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ASSESSMENT OF COLOR-MEASURING INSTRUMENTS FOR OBJECTIVE TEXTILE ACCEPTABILITY JUDGEMENT

by

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Three current color-measuring spectrophotometers (Diano Match-Scan, Hunter D54, Macbeth MS-2000) have been evaluated by Rensselaer Polytechnic Institute for NARADCOM. Each instrument was tested to assess its suitability for use in the objective judgment of textile shade acceptability. The program included studies of the accuracy and repeatability of color measurement, the precision of color difference measurement, the sensitivity of the instruments to various sample and measurement parameters, and the statistical evaluation of the distributions of the data obtained.

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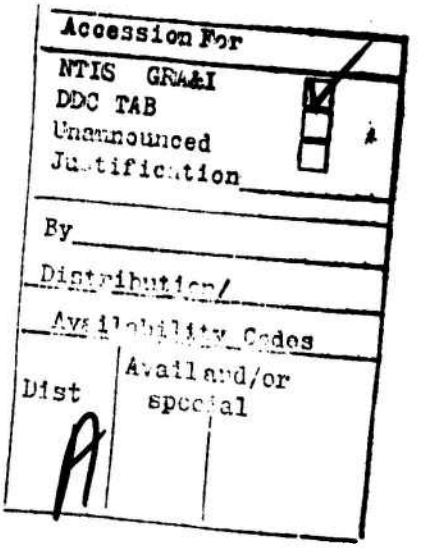
EXECUTIVE SUMMARY

Each of the three color-measuring instruments tested has adequate short-term and long-term repeatability and adequate accuracy to carry out the necessary measurements for NARADCOM's proposed program of objective textile acceptability judgments.

However, none of the instruments is fully satisfactory for the proposed program from operational and computational points of view. Modifications of any of them will be required to achieve a completely suitable configuration, and these are identified and discussed.

With appropriate modifications, any of the three instruments tested should be suitable for NARADCOM's requirements.

It is therefore recommended that the final selection of the instrument for ultimate use in the program be made by NARADCOM after consultations with the manufacturers regarding modifications.



PREFACE

The US Army Natick Research and Development Command has undertaken a program to develop an instrumental method for assessing the acceptability of textiles for color. It is intended that an objective procedure will evolve that can replace the subjective method of inspection that is now used.

The program has been planned in four consecutive phases.

Phase I: Survey of Commercial Instruments

Phase II: Design of System

Phase III: System Assembly and Validation

Phase IV: System Field Trial

Phase I is nearing completion. This report, together with in-house studies and experience, will provide the basis for selection of system components for the system design of Phase II.

The Project Officer is Mr. Alvin O. Ramsley, who expresses his thanks to Dr. Billmeyer and Miss Alesi for a very comprehensive piece of work. He also wishes to thank the National Research Council Committee on Color Measurement for their advice on the first and second phases of the program.

He gratefully acknowledges the help he has received in both managerial and technical aspects of the work from Mr. John V. E. Hansen, Mr. Charles R. Williams and Miss Therese R. Commerford, all of the Clothing, Equipment and Materials Engineering Laboratory at the Natick R&D Command.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PAGE

ASSESSMENT OF COLOR-MEASURING INSTRUMENTS FOR OBJECTIVE TEXTILE ACCEPTABILITY JUDGMENTS

I. INTRODUCTION

The use of instrumental methods for color quality assurance, based on acceptability judgments and using textile samples, has been demonstrated in a number of commercial situations. Several authors[1-4] have shown that instrumental shade passing is significantly more reliable than the corresponding visual task. The main thrust of this research is to identify instrumented systems providing substantially more reliable data than visual observation methods for the assessment of the surface color of textile samples for conformance to shade and tolerance for military purchase of fabrics. The research has been carried out on behalf of, and in cooperation with, the U.S. Army Natick Research and Development Command (NARADCOM).

The Rensselaer Color Measurement Laboratory (hereafter, "this Laboratory") has studied the comparative performance of color-measuring instruments and published[5,6] on the subject. We have long held the point of view that the instruments themselves are capable of discriminating reliably color differences smaller than those which can be seen, even under the best conditions for visual observation. What remains is to prepare and present to the instruments samples which are reproducible, and can be measured reproducibly, to the same degree. We have previously demonstrated the feasibility of doing this with painted papers in our own researches on small color differences. Application to textile samples can present more severe problems, and feasibility for NARADCOM's specific interests is demonstrated in this report.

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1. S. M. Jaekel, "Utility of Color Difference Formulas for Match-Acceptability Decisions," Appl. Optics 12, 1299-1316 (1973).

2. K. Jelsch and X. Fink, "Analysis of Errors in Acceptability Experiments," J. Soc. Dyers Colourists 92, 227-232 (1976).

3. K. McLaren, "An Introduction to Instrumental Shade Passing and Sorting and a Review of Recent Developments," J. Soc Dyers Colourists 92, 317-326(1976)

4. S. M. Jaekel and C. D. Ward, "Practical Instrumental Color Quality Control—the Hatra Experience," J. Soc. Dyers Colourists 92, 353-363 (1976).

5. F. W. Billmeyer, Jr., "Comparative Performance of Color-Measuring Instruments," Appl. Optics 8, 775-783 (1969).

6. F. W. Billmeyer, Jr., E. Campbell, and R. Marcus, "Comparative Performance of Color-Measuring Instruments; Second Report," Appl. Optics 13, 1510-1518 (1974); ibid., "Authors' Reply to Comments," Appl. Optics 14, 275 (1975).

Within the last year several new instruments have been marketed which appear to offer significant advantages in speed and convenience, including built-in computer capability, while retaining the precision and reproducibility of previous models, all at moderate cost. It is from among these newer instruments that we have designated those capable of performing the task defined in the program.

II. INSTRUMENTS STUDIED

The three instruments studied in this project have been compared qualitatively in recent papers[7,8] from this Laboratory as well as in the separate references cited.

A. Macbeth MS-2000 Spectrophotometer.

The Macbeth MS-2000 spectrophotometer[9] is an abridged double-beam instrument with several novel features. A block diagram is given in Figure 1. The light source is a pulsed-xenon flashtube, optically filtered to simulate CIE Standard Illuminant D_{65} (hereafter simply D_{65}). An alternative filter simulating CIE Standard Illuminant A (hereafter, Ill. A) is available. The MS-2000 utilizes integrating-sphere geometry with diffuse irradiation and 8° viewing. In each measurement the flashtube is fired four times (20-30 micro second duration pulses) with the sample viewed during two pulses and the sphere wall, as an internal reference, during the other two. A fixed grating monochromator projects the viewing beam onto an array of 17 silicone-photodiode detectors, centered at 20 nm intervals from 380-700 nm, with a spectral width of 16 nm each. The seventeen signals produced simultaneously at each firing of the flashtube are amplified to produce a logarithmic photometric scale. A microprocessor and cathode-ray tube for data handling and output are included.

B. Hunter D54P-5 Spectrophotometer.

This instrument[10] is a single-beam scanning spectrophotometer. A block

7. F. W. Billmeyer, Jr. and D. C. Rich, "Color Measurement in the Computer Age," Plastics Eng. 34 (12), 35-39 (1978).

8. D. C. Rich and F. W. Billmeyer, Jr., "Practical Aspects of Current Color-Measurement Instrumentation for Coatings Technology," J. Coatings Technol. 51 (650), 45-47 (1979).

9. S. J. Kishner, "A Pulsed-Xenon Spectrophotometer with Parallel Wavelength Sensing," in Fred W. Billmeyer, Jr., and Gunter Wyszecki, Eds., Color 77, Adam Hilger, Bristol, 1978, p. 305-308.

10. J. S. Christie and G. McConnell, "A New Flexible Spectrophotometer for Color Measurements," in Fred W. Billmeyer, Jr., and Gunter Wyszecki, Eds., Color 77, Adam Hilger, Bristol, 1978, p. 309.

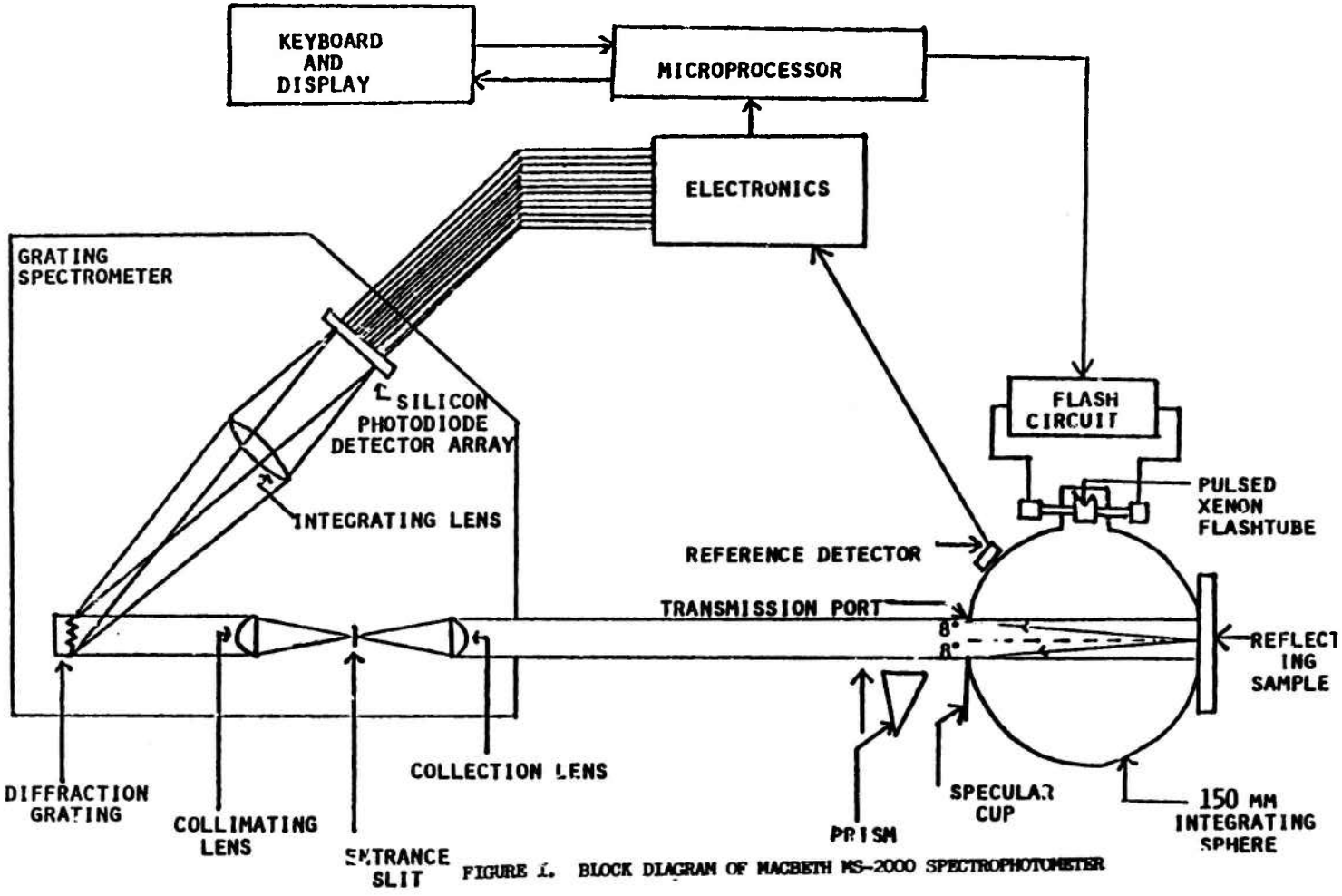

FIGURE 1. BLOCK DIAGRAM OF MACBETH MS-2000 SPECTROPHOTOMETER

diagram is given in Figure 2. The source is a quartz-halogen tungsten-filament lamp optically filtered to simulate D_{65}. On special order, the instrument can be modified to operate with the filter removed, producing a Planckian source probably higher in color temperature than Ill. A. Integrating-sphere geometry is used with diffuse irradiation and 8° viewing. The viewing beam is projected onto a rotating interference-wedge monochromator and then to a silicon-photodiode detector. The spectral bandpass is about 10nm at 400 nm and 18 nm at 700 nm. The instrument is optically identical with the Applied Color Systems Spectro Sensor.[11]

Single-beam integrating-sphere instruments are subject to a photometric scale error[12,13] which is corrected in the microprocessor of the D54. An additional calibration step is required to test the accuracy of the correction. Output is by means of a thermal printer.

C. Diano Match-Scan Spectrophotometer

The Match-Scan is a double-beam spectrophotometer of essentially conventional design. Its block diagram is shown in Figure 3. The source is a quartz-halogen tungsten-filament lamp which can be operated without filter as CIE Standard Source A or optically filtered to simulate D_{65}. Integrating-sphere geometry with diffuse polychromatic irradiation and 8° viewing is standard, but 8° monochromatic irradiation and diffuse viewing is available as an option. The diameter of the viewing beam can be varied from 20 mm to about 2 mm. A Bausch and Lomb single-pass grating monochromator is used, with the spectral bandpass fixed at 10 nm. Potentially, the wavelength range is 200 - 1000 nm, but standard components and software limit the useful range to the usual 400 - 700 nm. The detector is a photomultiplier tube. The minicomputer provided has greater potential capacity than the microprocessors in the Macbeth and Hunter instruments. Output is by means of a Decwriter or equivalent typewriter.

III. EXPERIMENTAL PROCEDURE

A. Samples

A complete listing of all the samples used in this study was given in

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11. R. Stanziola, B. Momiroff, and H. Hemmendinger, "The Spectro Sensor—A New Generation Spectrophotometer," in F. W. Billmeyer, Jr., and Gunter Wyszecki, Eds., Color 77, Adam Hilger, Bristol, 1978, pp. 313-315, and Color Res. Appl. 4, in press (1979).

12. A. C. Hardy and O. W. Pineo, "The Errors Due to Finite Size of Holes and Sample in Integrating Spheres," J. Opt. Soc. Am. 21, 502-506 (1931).

13. D. C. Goebel, "Generalized Integrating Sphere Theory," Appl Optics 6, 125-128 (1967).

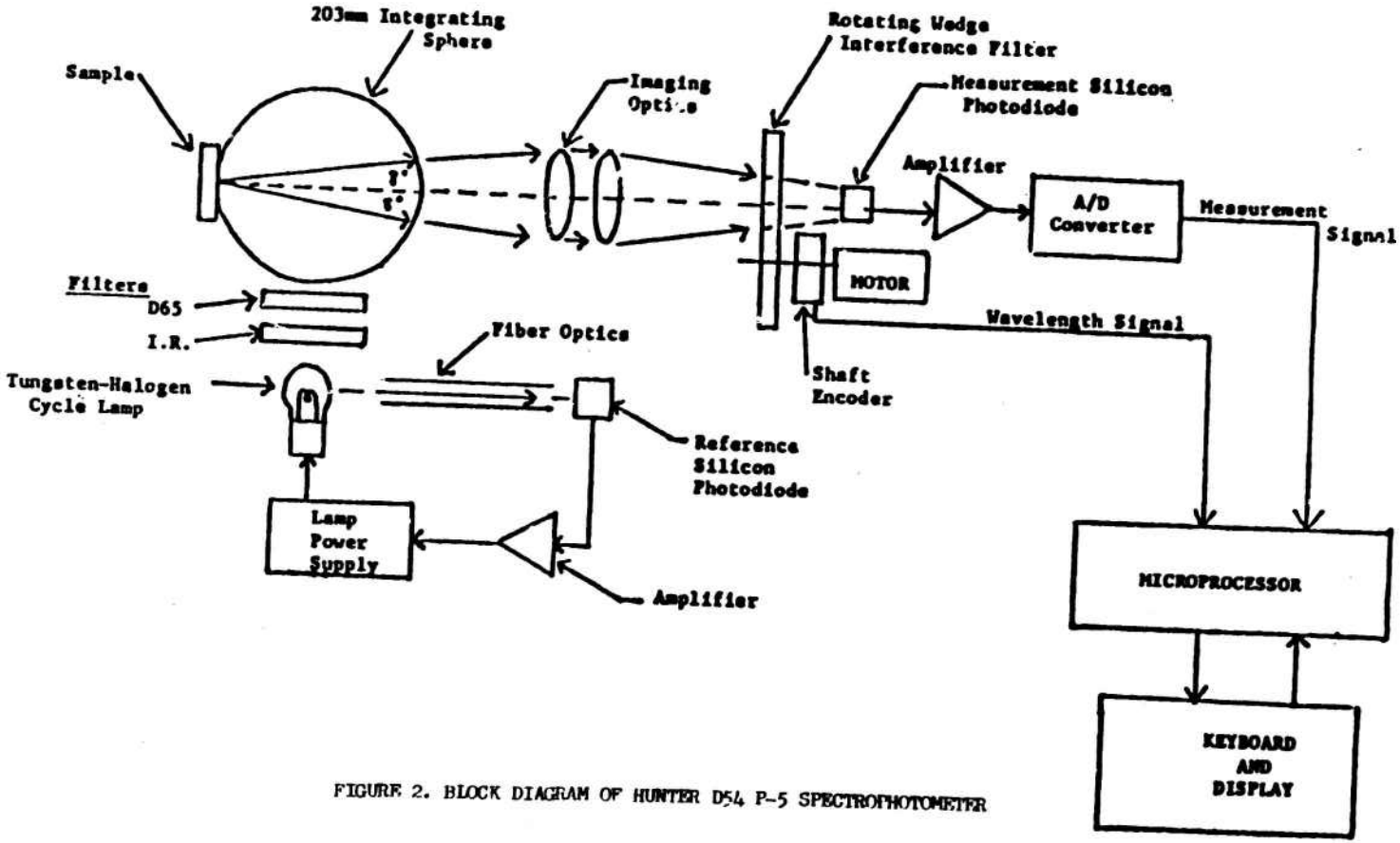

FIGURE 2. BLOCK DIAGRAM OF HUNTER D54 P-5 SPECTROPHOTOMETER

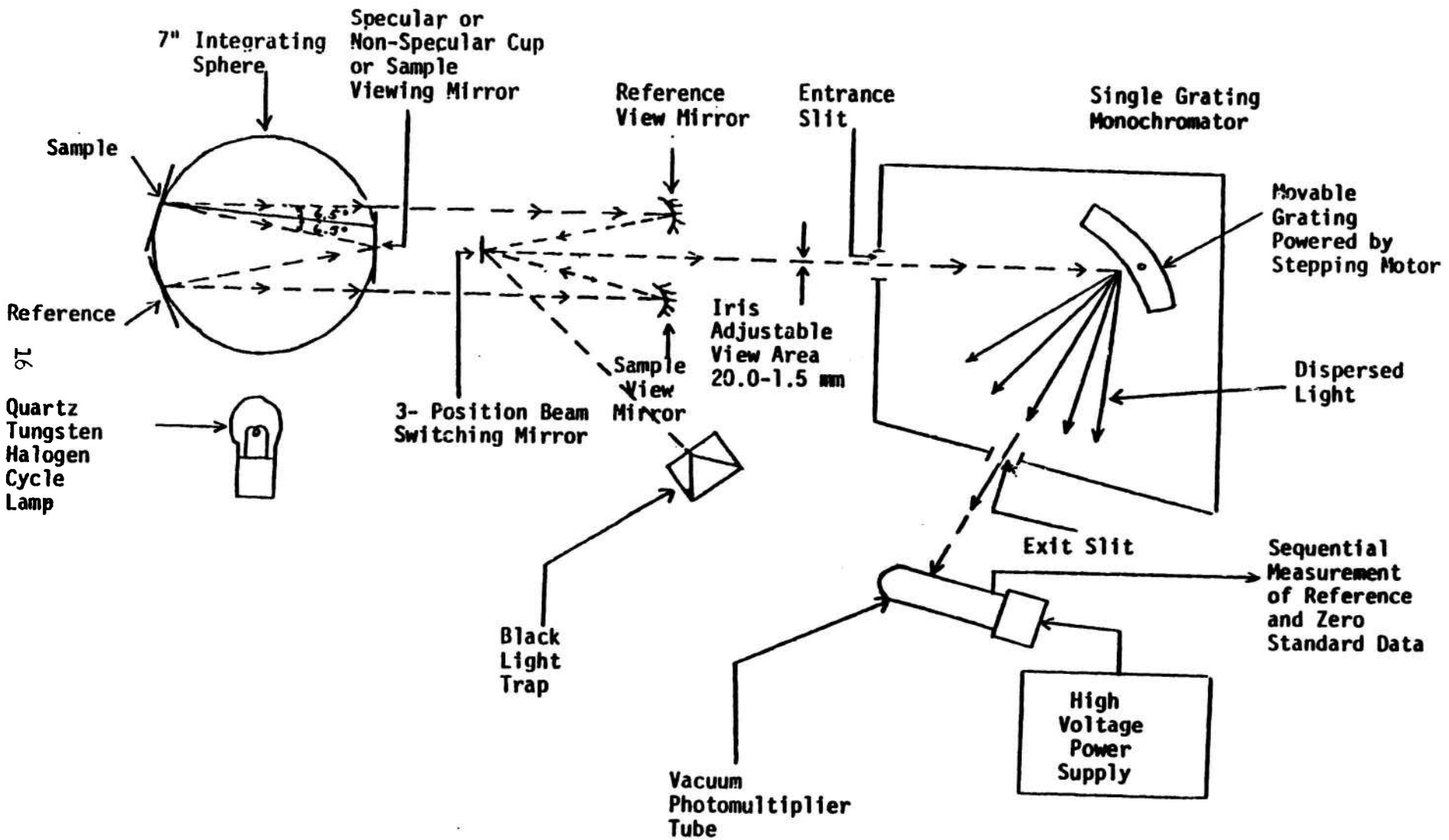

FIGURE 3. BLOCK DIAGRAM OF DIANO MATCH-SCAN SPECTROPHOTOMETER

Progress Report No. 1.[14] They fall into three groups:

1. Textile Color-Difference Sets.

Sixteen sets were obtained from NARADCOM, each consisting of eight visual acceptability limit standards around a central target standard. These samples were used to test short-term and long-term repeatability of color measurement, precision of color-difference measurement, sensitivity to orientation of textile weave, and several other parameters.

2. Calibrated Standards

The major calibrated standards used were NBS Standard Reference Materials 2101-2105, a set of transmitting filters,[15,16] and the British Ceramic Research Association (BCRA) Reflecting Tiles,[17] calibrated at the Hemmendinger Color Laboratory. These samples were used primarily to test accuracy of color measurement.

3. Miscellaneous Samples

Other samples selected to test specific parameters or to provide a wider variety of sample characteristics included the following: porcelain-enamel tile color-difference sets obtained from NARADCOM and used in previous studies[18,19] on instrument performance from this laboratory; gray tiles[20] from Johnson in England useful to test photometric scale performance; fluorescent papers; and a variety of tiles with various surface characteristics.

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14. P. J. Alessi and F. W. Billmeyer, Jr., "Assessment of Color-Measuring Instruments for Objective Textile Acceptability Judgments; Progress Reports No. 1 (January 27, 1978), No. 2 (April 21, 1978), No. 3 (July 21, 1978), and No. 4 (October 24, 1978), "Unpublished, on file at NARADCOM.

15. H. J. Keegan, J. C. Schleter, and D. B. Judd, "Glass Filters for Checking the Performance of Spectrophotometer-Integrator Systems of Color Measurement," J. Res. Natl. Bur. Stand. 66A, 203-211 (1962).

16. K. L. Eckerle and W. H. Venable, Jr., "1976 Remeasurement of NBS Spectrophotometer-Integrator Filters," Color Res Appl. 2, 137-141 (1977).

17. F. J. J. Clarke, "Ceramic Colour Standards—An Aid for Industrial Color Control," Printing Technology 13, 101-113 (1969).

18. See footnote 5.

19. See footnote 6.

20. A. R. Robertson and W. D. Wright, "An International Comparison of Working Standards for Colorimetry," J. Opt. Soc. Am. 55, 694-706 (1965).

B. Measurement Procedures

A variety of white standards was used depending on instrument requirements. White ceramic tiles calibrated to the 1977 NBS scale of absolute reflectance[21] at the Hemmendinger Color Laboratory were used where possible. For inter-instrument comparisons, Eastman White Reflectance Standard[22] (pressed barium sulfate) was used and was either assigned a reflectance factor of 100 at each wavelength, or assigned absolute reflectance factors from the literature.[23]

Measurements were performed with the specular component either included or excluded (hereafter SIN or SEX, respectively) depending on the sample and test. Most textile measurements were made with the specular component included (SIN mode).

For uniformity of practice, CIE 1976 $L^* a^* b^*$ (CIELAB) color coordinates and color differences[24] were routinely used. They were computed for D_{65} and the 1931 CIE Standard Observer.[25] In some cases, especially for comparison with literature values, CIE 1931 tristimulus values, Standard Illuminant C, and FMC-2 color differences[26] were computed.

21. See footnote 16.

22. Eastman White Reflectance Standard (barium sulfate), Catalog No. 6091, Eastman Kodak Company, Rochester, N.Y. 14650.

23. F. Grum and T. E. Wightman, "Absolute Reflectance of Eastman White Reflectance Standard," Appl. Optic 16, 2775-2776 (1977).

24. Recommendations on Uniform Color Spaces, Color-Difference Equations, and Psychometric Color Terms," Supplement No. 2 to CIE Publication No. 15, Colorimetry, E-1.3.1 (1971), Bureau Central de la CIE, Paris, 1978.

25. Publications CIE No. 15 (E-1.3.1) 1971, Colorimetry, Bureau Central de la CIE, Paris, 1971; Supplement 1, 1972; Available from the U.S. National Committee, CIE, National Bureau of Standards, Washington, D.C. 20234.

26. K. D. Chickering, "FMC Color Difference Formulas: Clarification Concerning Usage," J. Opt. Soc. Am. 61, 118-121 (1971).

IV. RESULTS

The purpose of this section is to present brief details of experimental procedures and to indicate in which of the accompanying Tables the corresponding numerical data are to be found. Discussion of results is included under corresponding headings in Section V.

A. Repeatability of Color Measurement

1. Short-Term Repeatability

a. NBS SRM 2101-2105 Filters. Each sample was measured 5 times (on one instrument, 3 times), being removed and replaced between measurements. The CIELAB color difference was calculated between the tristimulus values (III. C) for each measurement and the mean tristimulus values for the 5 (or 3) measurements. These color differences were then averaged, and the table reports these averages and their standard deviations. Hereafter quantities calculated in this way will be referred to as "means of color differences from the mean of a set of measurements" or MCDM's. These MCDM's, listed in Table 1a, are measures of the short-term repeatability of the instruments for these transmitting filters.

b. BCRA Tiles. Each BCRA tile was measured five times (SEX mode) without moving the sample. The MCDM's and their standard deviations are reported in Table 1b. (In this instance, they were calculated for D_{65}.) They represent the short-term repeatability of the instruments for reflectance measurement of (largely) nonfluorescent tiles; see also the next paragraph.

c. Fluorescent Samples. MCDM's for highly fluorescent samples, measured as in paragraph b above but in the SIN mode, are presented with their standard deviations in Table 1c.

2. Combined Short- and Long-Term Repeatability Studies

a. BCRA Tiles. The 12 BCRA tiles were each measured 5 times, once in the center and once in each corner with 90° rotation between measurements, once a week for 8 weeks. The SEX mode and D_{65} were used. MCDM's were calculated between the mean of each week's results, providing long-term repeatability data. All these MCDM's and their standard deviations are given in Table 2a. Some short-term results on the NARADCOM Diano-Hardy II (SIN mode) are included.

b. NARADCOM Textile Samples. The target standard for each NARADCOM textile set, folded to infinite thickness, was measured in 5 different areas, holding the weave orientation constant, once a week for 8 weeks. MCDM's for short-term and long-term repeatability were calculated as in paragraph a above and are presented in Table 2b. Some samples were also measured on the NARADCOM Diano-Hardy II and on an engineering prototype Hunter D54 using $45^{\circ}/0^{\circ}$ illuminating-viewing geometry. These are included. In all these measurements, the SIN mode and D_{65} were used.

3. Other Long-Term Repeatability Studies

Ten "Carrara" glass tiles were measured (SEX mode, D_{65}) once a week for 8 weeks. MCDM's and their standard deviations are given in Table 3. In this instance, weekly results are included to provide an idea of the distributions of values obtained.

B. Precision of Color-Difference Measurement

1. NARADCOM Porcelain-Enamel Tiles

For each set of tiles, three measurements were made (SEX mode, D_{65}), and CIELAB color differences calculated between the standard and the "high" limit sample, and between the standard and the "low" limit sample. The means and standard deviations of these color differences are given in Table 4a. (For the reason for two sets of measurements for the Hunter instrument, see Progress Report No. 4.[27]).

Coefficients of variation, Cv, were also calculated.[28] Cv is the standard deviation expressed as a fraction of the mean. Average values of Cv are given in Table 4b, together with their standard deviations.

2. NARADCOM Textile Samples

Each sample in the 16 textile sets was measured three times in each of three different weave orientations: 0°, 45°, and 90° with reference to the standard orientation (SIN mode, D_{65}). Color differences were calculated, at fixed orientation, between each limit standard and the target. The means and standard deviations of these color differences are presented in the 16 Tables 5a - 5p. In a few cases, as noted, 6 measurements instead of 3 were made.

Values of Cv were then calculated and averaged over the 8 samples of each set. These values are presented, for the three orientations, in Tables 5q - 5s.

27. See footnote 14

28. M. G. Kendall and A. Stuart, The Advanced Theory of Statistics, Vol. 1, Distribution Theory, 2nd ed., Hafner, New York, 1963.

C. Accuracy of Color Measurement

1. NARADCOM Porcelain-Enamel Tiles

Of all the samples used in earlier studies[29,30] of the comparative performance of color-measuring instruments in this Laboratory, only the NARADCOM tile sets proved useful for remeasurement. The original data[31] were treated slightly differently for the present study: Tristimulus values from Rensselaer's G. E.-Hardy spectrophotometer (SEX, III. C) were used to calculate three FMC-2 color differences for each pair. The means and standard deviations of these values are given in the first column of Table 6. Data obtained in the same way using the instruments currently under study appear in the remainder of the table.

2. NBS SRM 2101-2105

The 1976 remeasured transmittances[32] of the master set of SRM 2101-2105 were adjusted to correspond to the thicknesses of the samples of Rensselaer's Set No. 31. These data were integrated (at 20-nm intervals using III. C) and CIELAB coordinates were generated. From the measurements of this set described in Section IVA1a, transmittances were similarly integrated, and color differences from the corrected NBS values were calculated. The means and standard deviations of these are given in Table 7.

3. BCRA Tiles

The reflectance-factor obtained in Section 1VA2a during the 8-week repeatability study (SEX mode) were adjusted to the 1977 NBS absolute reflectance scale and integrated (20 nm interval, D_{65}). Data supplied by the Hemmendinger Color Laboratory were treated[62] in the same manner. CIELAB color differences were generated and averaged for each week. Their means and standard deviations appear in the first 8 columns of Table 8a. The five sets of CIELAB coordinates obtained (for each sample) in a single week were then averaged, and the color difference calculated between the average and the Hemmendinger data. The resulting color differences were averaged over the 8 weeks to give the means and standard deviations in the last column of Table 8a. (The results in this Table differ significantly from those in Progress Report No. 4[33] where the method of integrating the reflectance-factor data was not standardized.)

29. See footnote 5

30. See footnote 6

31. See footnote 5

32. See footnote 16

33. See footnote 14

It was desired to obtain data in the SIN mode also. For the Hunter and Match-Scan instruments, each tile was measured on five days as in Section IVA2a except for change of mode. The data were treated as above; the results are given in Table 8b. Similar results were taken from duplicate daily performance test measurements on all the spectrophotometers; these data are those given in Table 8c. (Again, these data differ from those given in Progress Report No. 4, because of differences in mode of integration.)

D. Sensitivity to Other Parameters

1. Weave Orientation of Textiles

The "thin standard" and "full standard" limit samples from each NARADCOM textile set were used to compare measurements of the same area after rotation of 45° and 90° from the standard position. Three sets of measurements were made (SIN mode). The mean color differences and their standard deviations are given in Tables 9a and 9b. An abbreviated study was made on the prototype Hunter 45°/0° D54 spectrophotometer, which irradiates the sample from a single azimuthal angle. Color differences obtained on 90° rotation are given in Table 9c.

2. Rejection of Specular Component

a. Glossy-Sample Repeatability. A variety of glossy materials ranging from polished "Carrara" glasses to painted samples was used to obtain color differences among three repeat measurements, for both the SEX and SIN modes. MCDM's (see explanation in Section IVA1a) and their standard deviations are given in Table 10a.

b. Glossy-Sample Spectral Differences. The differences in reflectance factors obtained in the above measurements were averaged over the 16 wavelengths at 20 nm intervals, 400-700 nm. The averages and standard deviations are given in Table 10b.

c. Textile-Sample Repeatability. Each NARADCOM textile standard was measured, in both the SIN and SEX modes, 5 times each week for 8 weeks. Reflectance-factor data were adjusted to compensate for week-to-week changes in reflectance levels, and MCDM's were calculated for each mode. These are given in Table 10c. A few measurements for one instrument at one week were thought to be in error; MCDM's calculated with these spurious results omitted are given in parentheses.

d. Textile-Sample SIN-SEX Differences. To compare values obtained in the two modes for the textile samples, color differences were calculated between the grand means (5 measurements per week, 8 weeks) in the SIN and SEX modes. They are tabulated for each textile standard and instrument in Table 10d.

3. Differences Among Photometric Scales

Although calibrated nonselective neutral samples, which would have allowed tests of accuracy of the photometric scales of the instruments, were not available, it was of interest to compare these scales in a relative way. For this purpose 11 Johnson gray tiles (10 on the Match-Scan) were measured 11-15 times on each instrument. Values of CIE Y (D_{65}) were averaged, then scaled to assign the lightest tile $\bar{Y} = 100$. Then a grand mean over all instruments, $\bar{\bar{Y}}$, was calculated. Table 11 provides values of the number of measurements, n; $\bar{Y}$; $\bar{\bar{Y}}$; and the differences $\bar{Y} - \bar{\bar{Y}}$. The latter are plotted in Figure 4.

4. Point-to-Point Specimen Variations

To test the sensitivity of the instruments to point-to-point variations within a single specimen, repeatability data reported in Section IVA2 were treated to calculate color differences between averaged measurements at the center of a specimen and at each of its four corners. These color differences are reported as follows:

Table 12a shows data for the BCRA tiles (SEX mode, D_{65}), taken from the 8-week repeatability data given in Section IVA2a. Table 12b contains data for these tiles (SIN mode, D_{65}) taken from the duplicate measurements reported in Section IVC.3 (Table 8c). Table 12c contains data (SIN mode, D_{65}) for the textile samples taken from the 8-week repeatability study in Section IVA2b.

5. Short-term Calibration Stability. With the Hunter and Match-Scan spectrophotometers, a white tile was measured immediately after each calibration, and again just before recalibration. The time interval between these measurement pairs was 15 to 30 minutes, corresponding to the measurement of 20 samples. Four such sets of measurements were made each week as part of the 8-week textile repeatability study reported in Section IVA2b. The grand mean color difference (SIN mode, D_{65}) for both instruments was 0.034 CIELAB units.

E. Statistical Evaluation of Distributions of Colorimetric Data Obtained

The 8-week repeatability studies performed on the textile standards (Section IVA2b) provide enough data to model the frequency distributions of the colorimetric data obtained. Parametric statistical testing of significance with techniques such as analysis of variance or multiple regression and the determination of confidence and tolerance intervals can be applied validly only if the data under investigation are from a statistical normal distribution. Of primary interest are the distributions of spectral reflectance factor or spectral transmittance obtained in this project, but the number of data points involved makes it expedient to test tristimulus values for normality instead. Since they are linear transformations (i.e., weighted sums) of the spectral data, it can be assumed that the latter are normally distributed if the tristimulus values are. In contrast, CIELAB coordinates, which are nonlinear transformations (cube roots) cannot be expected to show similar normality

characteristics.

1. Characteristics of Tristimulus Value Distributions

For comparison to the statistical normal distribution, tristimulus values X, Y, and Z are transformed into standard normal deviates, A, which have means of zero and standard deviations of one:

$$A_i = (W_i - \bar{W})/\sigma \qquad (1)$$

where W can be X, Y, or Z, the bar indicates a mean, and σ is its associated standard deviation.

One measure of normality is the percentage of values falling within $\pm$ 1σ or $\pm$ 2σ of the mean (67% and 95%, respectively, for the normal distribution). Tables 13a - 13c present these percentages for the standard normal deviates of X, Y, and Z, respectively, for the weekly textile measurements. Values in parentheses for the Hunter D54 omit measurements suspected of being in error for one week, throughout this Section.

Another measure of normality is the shape of the distribution. This can be characterized[34] by its skewness and kurtosis, calculated from the moments M_j of the distribution:

$$M_j = (1/n) \sum_{i=1}^{n} (A_i - \bar{A})^j \qquad (2)$$

It can be seen that the mean is M_1 and the standard deviation, M_2.

The skewness is defined as $M_3/M_2)^{3/2}$. It measures the lack of symmetry of a distribution around its mean. The kurtosis is $(M_4/M_2^2) - 3$. It measures the sharpness of the peak of the distribution. The normal distribution has skewness and kurtosis of zero.

Relative frequency distributions of the standard normal deviates of the tristimulus values for the weekly textile measurements appear on inspection to be slightly skewed toward higher values and to be multimodal, having two to four or more peaks. Tables 13d - 13f give their skewness and kurtosis. From the sample size it is possible to estimate[35] the range of these parameters expected for a normal distribution; values deviating from normality are indicated by asterisks in these tables; the estimates are considered to be very conservative.

34. G. W. Snedecor and W. G. Cochran, Statistical Methods, 6th ed., Iowa State University Press, Ames, 1967.

35. See footnote 34.

2. Lilliefors Goodness of Fit Test

The Lilliefors test[36] determines how well a data set fits the normal distribution. The Lilliefors test statistic, D, is given by

$$D = \max_W \left| F(W) - S_n(W) \right| \qquad (3)$$

where $S_n(W)$ is the cumulative distribution function for the nth sample and $F(W)$ is the cumulative normal distribution function. Values of D indicative of departure from normality at various levels of significance can be specified. The Lilliefors test is considered to be more powerful than the chi square test. Table 14 refers to D for X, Y, and Z for the weekly textile measurements. Asterisks indicate where values of D deviate from normality at the indicated levels of significance.

3. Nonparametric Multicomparison Tests

The nonparametric analog of an analysis of variance, applicable to distributions which are not normal, is known as the Friedman two-way analysis of variance by rank sums.[37] It does not require knowledge of the means of variances (squares of standard deviations) of the data being studied. It assumes that each data point has a value equal to the (unspecified) mean perturbed by error terms originating independently from each variable—in our case, for example instrument, week of measurement, etc. With slight modification, interactions among these variables can be explored.

The Friedman tests were applied only to tristimulus value Y, since X and Z appear to be similar to Y in the other tests for normality employed. The results are summarized in the following tables merely by noting situations in which differences exist which are significant at the 0.01 level. The tables are abbreviated in that many columns and rows for which there are no entries have been omitted.

Table 15a is concerned with differences among instruments. The interpretation of the tabulated data is, for example, that the 40 measurements (5 positions on each of 8 weeks) of the Tan 445 sample obtained on instruments 1 and 3 were significantly different with 99% probability.

Similarly, Table 15b provides comparisons among measurements on different weeks, and Table 15c shows instrument vs. weekly interactions.

36. W. H. Lilliefors, "On the Kolmogorov-Smirnov Test for Normality with Mean and Variance Unknown," J. American Statistical Association 62, 399-402 (1967).

37. M. Hollander and D. A. Wolfe, Nonparametric Statistical Methods, John Wiley and Sons, New York, 1973.

V. DISCUSSION

A. Repeatability of Color Measurement

Averaging color differences over all samples in each repeatability study leads to summary results, in the form of means and standard deviations, presented in Tables 16 and 17.

The data in Table 16 show each instrument's precision of measurement of the same area of a sample. The results are virtually identical for non-fluorescent and fluorescent samples, on a short-term basis.

Although examination of long-term means suggests some differences in performance among the three NARADCOM instruments, these are not statistically significant, all the means falling within one standard deviation of one another. We can conclude that the NARADCOM MS-2000, D54, and Match-Scan instruments perform identically over both short and long (8-week) periods. The Kollmorgen MS 2000 repeatability appears to be slightly poorer, but we have no evidence that this demonstrator instrument was in perfect operating condition.

The data in Table 17 refer to point-to-point variations over a sample. The best performance is found with NBS SRM 2101-2105, not surprising in view of the uniformity of these filters. Parenthetically, the thermochromic nature of the selenium red filter, 2101, is thought to be responsible for poorer repeatability for this sample when direct incandescent sphere illumination is used, as in the NARADCOM Match-Scan and the D54. With this exception, the short-term means for these samples measured on the various instruments all fall within one standard deviation.

Similarly, the long-term grand means for the BCRA tiles and for the textile samples fall within one standard deviation when the various instruments are compared. Thus there is no basis in terms of repeatability to state that one instrument is better than another.

Finally, it is remarkable that in no case is the mean color difference from a mean greater than about 0.1 CIELAB unit in all the tests performed.

B. Precision of Color-Difference Measurement

In this section, results are discussed in terms of coefficients of variation because it is a measure of the spread among the measurements which does not vary with the size of the mean.

The coefficients of variation of the measurements of the NARADCOM porcelain-enamel tiles, given in Table 4a, were averaged over all the samples and are summarized in Table 18. Again, examination of the corresponding standard deviations shows complete overlapping, so that all results fall within one standard deviation for the respective instruments.

Similarly, examination of the results for the NARADCOM textile samples in Tables 5a - 5s show some trends, which are summarized by averaging over all samples in Table 19. Again, examination of the standard deviations for the worst case (Blue 150 Trop. Wool) demonstrates that the means for the different instruments fall within one standard deviation. The conclusion is that the precision of textile color-difference measurements is statistically the same for all three instruments.

C. Accuracy of Color Measurement

1. NARADCOM Color-Difference Tiles

Very few conclusions can be drawn from the comparison of the FMC-2 color differences calculated from measurements of color-difference pairs among the NARADCOM tiles on the present instruments and on Rensselaer's Hardy spectrophotometer, taken as the referee instrument in the 1969 comparative performance study from this Laboratory.[38] Deterioration of the surfaces of the tiles, and the obviously lower precision of measurement of the earlier instrument, have apparently introduced random variations in the data far greater than those reported in the following paragraphs for newer calibrated standards. There seems to be no value in pursuing this cross-check with past results further.

2. NBS SRM 2101-2105 Filters

In reviewing the data for these filters in Table 7, we can see differences among instruments which we attribute primarily to spectral bandpass. The NBS 1976 remeasured data for the filters[39] were convoluted to a 10-nm bandpass. The best agreement with these data is shown by the Match-Scan, which also has a 10-nm bandpass. The D54, with a bandpass varying between 10 and 18 nm, shows next best agreement, and the MS-2000, with 16 nm bandpass, the poorest. The differences in the case of the MS-2000 are greatest for the 2101 red filter, which has the steepest spectral curve. All these differences are statistically significant at the one standard deviation level.

For the Match-Scan, the color differences from the NBS data are smaller for monochromatic illumination than the reverse; we see no clear reason to expect this even though these were the conditions of the original calibration.

38. See Footnote 5

39. See Footnote 16

3. BCRA Tiles

Measurement of the BCRA tiles in the SEX mode (Table 8a) shows a significant discrepancy between the Hunter D54 spectrophotometer and the calibration values, and a smaller trend in the same direction for the Match-Scan, which is not seen for the MS-2000 instruments. The difference is larger for darker colors, suggesting that it is associated with exclusion of the specular component. This was investigated further, as reported in Sections IVD2 and VD2, and measurements of the BCRA tiles in the SIN mode of five successive days were initiated; because of the sequential nature of this study the MS-2000 instruments were not included in this phase. These SIN-mode results; reported in Table 8b, indicate excellent accuracy for the D54 and for the Match-Scan in this mode. This is confirmed by short-term SIN-mode studies on all the instruments, reported in Table 8c. Considering minor differences in measurement geometry and spectral bandpass among the instruments, the absolute accuracy of all of them, in the SIN mode, is considered satisfactory. It should be noted that this level of accuracy can be achieved only by scaling the reflectance factor data to the same standard and using the same data and wavelength interval for integration; the better accuracy reported here than in Progress Report No. 4[40] results from the observation of these precautions.

D. Sensitivity to Other Parameters

1. Orientation

Although integrating-sphere instruments would not be expected to be sensitive to the weave orientation in textile samples, examination of the data in Table 9a and 9b shows that the NARADCOM Match-Scan exhibits statistical sensitivity to orientation for about 60% of the samples tested. To put the matter clearly beyond doubt, a small piece of the sample showing the largest sensitivity, OG 106 Ox./Nyl., was mounted on cardboard in order to eliminate sample variability, and measured on the Match-Scan at orientations differing successively by about 45°. The first reading was stored and color differences from this case obtained for the remaining orientations. The data are given in Table 20. The expected 180° cycle was observed, with maximum color differences at 90° and 270° of about 1.4 CIELAB color-difference units. The maximum color differences, at 180° and 360°,—as well as the grand mean color differences for the D54 and MS-2000 spectrophotometers in Tables 9a and 9b—are of the same order as the repeatability of color measurement established earlier.

40. See footnote 14

The color differences as a function of orientation shown by the Match-Scan are not as large as those measured for the same samples on the prototype Hunter $45^{o}/0^{o}$D54 spectrophotometer, exhibited in Table 9c. Subsequent discussion with the manufacturer elicited the information that a retardation plate is normally furnished with the Match-Scan to reduce the observed dependence upon sample orientation. At the time of the measurements, the retardation plate was not installed on the NARADCOM Match-Scan. Arrangements were made to have this component installed after the termination of this study.

2. Rejection of Specular Component

In view of the lower accuracy of the D54 and, to a lesser extent, the Match-Scan in the SEX mode, the behavior of all the instruments in rejecting the specular component was carefully assessed. It was first established, in Table 10a, that the short-term repeatability of the instruments was the same for both the SEX and SIN modes. This appears to be the case except for the ceramic tiles as measured on the D54 and MS-2000's. These samples probably have the poorest surfaces among those studied, and little weight is given to the slightly poorer SEX-mode repeatability in these cases. Similar data were excerpted from the long-term textile study (Table 10c) and again no significant differences between SEX-mode and SIN-mode repeatability were found, when the D54 results (in parentheses) omitting spurious values are compared.

The study of greatest interest in this area is that summarized in Table 10b, where differences in reflectance factor between the SIN and SEX modes are tabulated. It is clear that this difference is always greatest for the MS-2000's (particularly the Kollmorgen instrument), intermediate and almost equal for the Diano-Hardy and the Match-Scan, and least by far for the D54, regardless of sample type over a range of generally glossy samples.

Little absolute significance can be attached to the numbers since refractive indices are not known, hence Fresnel reflection coefficients cannot be calculated. For the "Carrara" glasses, however, this coefficient is expected to be near 4%. It thus appears that the SEX-mode readings obtained with the Hunter D54 are uniformly high, leading to smaller SIN-minus-SEX differences and poor agreement with calibration values where available.

One possible cause for the discrepancy could be tested: that there might be stray light in the transmission sample compartment of the D54 which was entering the sphere through the unprotected open specular port in the SEX mode. Experiments performed[41] at NARADCOM

41. T. R. Commerford, NARADCOM, private communication, February 9, 1979.

and reported in Table 21 demonstrate that this is not the case. Placing a black trap over the specular port made no significant change in the SIN-SEX readings for four "Carrara" tiles, two of which were the same color as samples tested at Rensselaer. Subsequent discussions with the manufacturer elicited the possibility that the discrepancy is related to the single-beam sphere efficiency correction factor, which is of necessity different between SEX-mode and SIN-mode operation. Experiments to confirm this had not been made at the termination of this study.

The problem is of little consequence for textile samples, however, because their specular component is so small. This is confirmed in Table 10d, which shows that (again omitting spurious results on the D54) the color differences between SEX-mode measurements are as small as or smaller than the long-term repeatability of color measurement for all textile samples and all instruments.

3. Differences Among Photometric Scales

Without spectrally neutral reflecting samples calibrated for luminance factor with high absolute accuracy it is not possible to assess the linearity of the photometric scales of the instruments in absolute terms. The data presented in Table 11 and plotted in Figure 4 do show that there are significant differences among them, exceeding 0.5% for $Y < 30$. Such differences are inexcusable in instruments designed for absolute work, but are of little consequence for color-difference measurement.

4. Point-to-Point Specimen Variations

The data presented in Tables 12a - 12c appear to reflect no more than statistical fluctuations in the measurements superimposed upon random small variations from point to point of the samples tested. It is not felt that useful conclusions can be drawn.

5. Short-Term Calibration Stability

The mean figure of 0.034 CIELAB color-difference units shift between successive calibrations is of the same order of magnitude as the repeatability of color measurement for samples with comparable surface uniformity.

E. Statistical Evaluation of Distributions of Colorimetric Data

1. Characteristics of Tristimulus Value Data

Confirming earlier conclusions from this Laboratory with older instruments,[42] all tests which were reported in Section IVE1 and IVE2

42. R. T. Marcus and F. W. Billmeyer, Jr., "Statistical Study of Color-Measuring Instrumentation," Appl. Optics 13, 1519-1530 (1974).

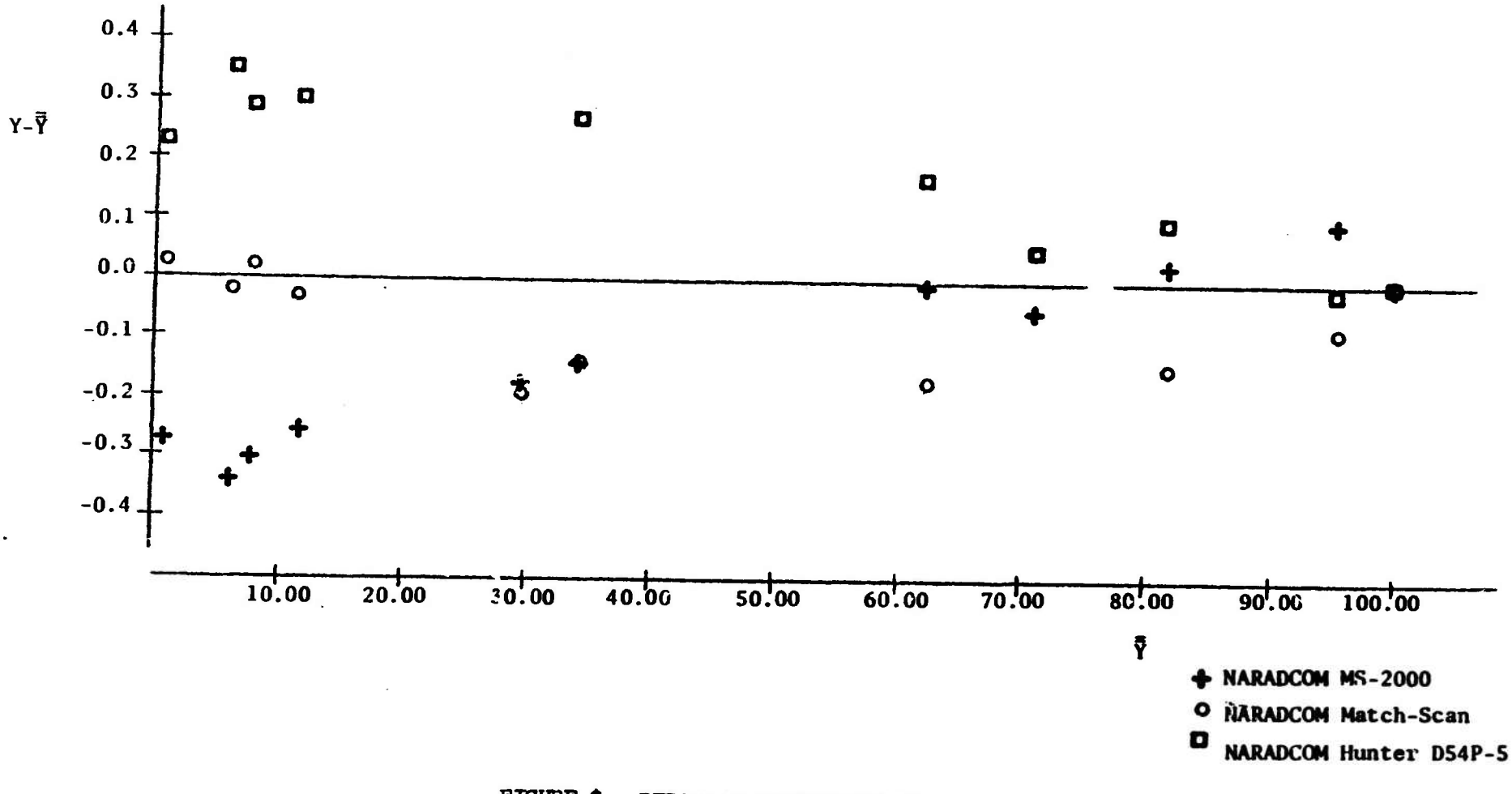

FIGURE 8. RELATIVE COMPARISON OF PHOTOMETRIC SCALES

show that the distributions of tristimulus values obtained in this study show large deviations from normality. It follows that the same conclusions apply to the underlying distributions of reflectance factors or transmittances. The standard normal deviate data in Tables 13a - 13c show that 70-80% of the points fall within one standard deviation of the mean, compared to 68.3% for the statistical normal distribution, and 97.5-100% within two standard deviations, compared to the expected 95.4%. Thus the observed distributions are more sharply peaked than normal. The kurtosis data in Tables 13d - 13f confirm this, and the skewness data in the same tables also indicate non-normality. Finally, the Lilliefors statistic departs from normality in a substantial fraction of the cases, as indicated by asterisks in Table 14. The conclusion stemming from these results is that nonparametric statistical tests are preferred for the evaluation of these or similar data.

2. Nonparametric Multicomparison Tests

From the nonparametric test results given in Tables 15a - 15c, the following conclusions can be drawn without bias from the non-normality of the data set:

The asterisks in Table 15a indicate that statistically significant differences occur frequently when results from either MS-2000 spectrophotometer are compared to those from the D54, or when the MS-2000's are compared to the Match-Scan. In contrast, the performance of the two Kollmorgen instruments is in general the same. Comparison of the Match-Scan with the D54 gives an intermediate case, with significant differences for some samples but not others. These discrepancies may be related to the differences in photometric scales discussed previously, or in unexplained ways to differences among samples, but no effort has been made to pursue the matter further.

Study of the results in Table 15b shows that only for six textile standards are there no significant week-to-week variations. For the remaining ten, significant differences appear to cluster in weeks 1-3 and 7-8, but a review of the work appears to offer no reason for this, especially since the measurements on different instruments were carried out at different time periods. It was noticed, however, that the samples most often showing significant variability, the two OD7 cotton ducks, were those which appear on visual examination to be the least uniform from point to point.

The data in Table 15c point out cross correlations between instruments and samples in any given week. Here, very few significant differences are found, again often associated with the cotton duck samples and probably attributable to their point-to-point variations.

VI. Conclusions and Recommendations

A. General Conclusion

In preparing the general conclusion of this study, we wished to compare the repeatability of instrumental color measurement with the sizes of the color differences to be measured. (We select the repeatability of color measurement rather than color-difference measurement since the former is expressed in terms of CIELAB color difference units, the latter in terms of coefficients of variation.) To estimate the sizes of the color differences to be measured, we averaged the mean color differences between the standard and each of the eight limit standards for each textile sample, using the data of Tables 5a - 5p, 0^{o} orientation. These averages are given in Table 22, for each instrument separately and for the three instruments taken together.

On the basis that the repeatability of color measurement (Section VA4) for all three instruments is better than 0.1 CIELAB unit, that the mean color differences in Table 22 are always larger than this, and in most instances much larger, and that the performance of the three instruments is statistically indistinguishable, we conclude that any of the three is suitable for the objective textile acceptability judgments contemplated.

B. Specific Comments on Instruments

Given the above general conclusion, it follows that the selection of the instrument to be used in subsequent phases of the NARADCOM study must rest in large part on factors other than their overall performance in terms of repeatability of color and color-difference measurements. In this section we address the advantages and disadvantages of the instruments, which are considered by manufacturers' name in alphabetical order.

1. Diano Match-Scan

a. Advantages. The Match-Scan is without question the most versatile and most research-oriented instrument of those tested. It is also the most conventional in design and construction, using well-tested standard components whose performance can be predicted with some assurance for a substantial future period. Its capability for illuminating the sample with both Ill. A and simulated D_{65}, and (not on the NARADCOM instrument) for the use of either monochromatic or polychromatic illumination, makes it by far the instrument of choice for measuring fluorescent samples. Its extended wavelength range is valuable for camouflage work. The ability to average repeat measurements (with point-to-point variation if desired) of either sample or

standard is provided. The diameterof the viewing beam (in polychromatic illumination) can be varied continuously down to about 2mm, and a series of apertures allows corresponding masking of the illuminated area—a more flexible arrangement than on the other instruments. The computer capacity of the instrument can be expanded substantially, but at significant extra cost.

b. Disadvantages. The Match-Scan is currently software limited in the stand-alone version. The NARADCOM instrument, for example, can provide tristimulus values for Ill. A, D_{65}, and cool white fluorescent, but not Ill. C. The instrument will operate over the wavelength range 200-1000 nm, but currently the data outside the color range (400-700 nm) cannot be corrected for 100% and 0% errors or scaled. (We understand that Diano is preparing software to add this capability for Ciba-Geigy.) Any modification of the calculations, after a measurement has been made, is not easily done. It often requires remeasurement, whereas the other instruments retain the spectral data for any desired sequence of computations. Nor can one enter the tristimulus values of a standard into the instrument, in order to compute color differences from a measured trial. (Spectral reflectance factors of a standard can be entered and used, however.) Tristimulus values are not always calculated from the best possible selection of standard illuminant and observer data, depending on the number of data points used. Sample presentation is limited for large samples unless a platform is removed; in this respect the Match-Scan is intermediate among the instruments tested.

In addition to these specific problems, a general disadvantage to the Match-Scan is that it takes a more skilled operator to use it than do the other instruments. It definitely is the least suitable for occasional casual use, as it presently is programmed. The problem of orientation sensitivity, discussed in Section VD1, must be resolved before the instrument can be recommended for textile work, but it has been reported that this is specific to the NARADCOM instrument and subject to correction.

2. Hunter D54

a. Advantages. The Hunter D54 spectrophotometer is relatively simple in construction. It has only one moving part (the shaft for the interference wedge), which should keep mechanical maintenance to a minimum. Although standard configurations do not allow illumination of the sample by both incandescent light and simulated daylight, this can be accomplished by mounting the D65 filter on the existing filter wheel

instead of in its usual position. The software is reasonable adequate, with new options being added frequently. Sample presentation arrangements are the best of those for any of the instruments tested. The potential exists for obtaining a modified interference wedge which would allow the instrument to operate in the near infrared region on keyboard command. Hunter Associates Laboratory has a good reputation in the field for repair, maintenance, and the willingness and ability to undertake special projects.

b. Disadvantages. The single-beam design of the D54 is a disadvantage as well as an advantage. Although it allows simple construction, it leaves photometric accuracy vulnerable to the condition of the coating of the integrating sphere. The need for an additional performance check to insure the applicability of the sphere correction factor encumbers the user, always prone to ignore calibration steps, with an extra responsibility. If this test is failed, he has no alternative procedure to repair the instrument, which superficially appears still to be working properly. The inability of the instrument to reject the specular component properly is a serious problem, which should be resolved by the manufacturer. Until the matter is resolved, we recommend that only SIN-mode measurements be made with the D54 spectrophotometer; this is not a severe disadvantage where the NARADCOM task is concerned, since this study has demonstrated that the specular component is insignificant for the NARADCOM textile samples. Averaging of readings for repeat measurements of sample and standard is not available on the NARADCOM D54, but we understand it is now offered as an option. Like the other instruments tested, the D54 is sold without an operating system for its microprocessor—that is, the user cannot write software programs for it.

3. Kollmorgen MS-2000

a. Advantages. A major advantage of the MS-2000 is the simplicity of its operation. All the controls are at hand and clearly marked; there are few decisions to make in order to get a measurement. The two MS-2000 spectrophotometers tested showed good inter-instrument agreement (there was no opportunity to test this for the other instruments). The MS-2000 has an interlock which insures that the SIN mode is being used when the readout says so, and similarly for the SEX mode. Sample heating is minimal on this instrument, and it is expected (though we did not confirm this) that the filtered xenon flashtube can provide a better simulation of Ill. D_{65} than the incandescent sources in the other instruments. The MS-2000 measures very rapidly, though its slower microprocessor makes the total time to an answer about the same as for the other instruments. Sample measurement averaging is available, and we understand that averaging of readings of the standard is available on newer instruments.

b. Disadvantages. The innovative design of the MS-2000 is accompanied by some inherent disadvantages. It is an abridged spectrophotophotometer, pure and simple. However, much of the presently foreseen NARADCOM work does not require smaller spectral bandpass and closer wavelength sampling. A second disadvantage is that the pulsed xenon lamp does not allow the option of direct incandescent illumination, though this can be easily simulated by filtering. Sample presentation arrangements are inconvenient. Large samples cannot be placed at the port satisfactorily, and samples cannot be shifted freely to select a specific area for measurement. Pressed powder transfer standards are subject to damage by the sample port configuration and surrounding surfaces. There are some limitations in the software: for example, it is not possible to enter and scale to the spectral reflectance factors of the user's white standard. One must either use the instrument standard provided or assign 100 to each spectral reflectance factor for whatever other standard is used. Finally, the logarithmic photometric scale introduces two disadvantages which are fortunately not serious for the NARADCOM project. First, there is an artificial lower limit of reflectance factor of about 0.1%, which can interfere with the measurement of true blacks or of transmitting samples of high absorbance at some wavelengths. Second, there is not adequate photometric resolution for near-whites.

4. General Disadvantages

All three of the instruments have some disadvantages which should be remedied by special modifications and/or programming before they can be considered satisfactory for NARADCOM's intended use.

a. Calibration. It is possible to miscalibrate any of the instruments in their present form. Any sample whatever can be placed at the measurement port and the calibration command given. The instrument will signify that a satisfactory calibration has been achieved. Some safeguards should be added: for example, measured values of the calibration standard or a performance test standard could be compared to those stored in memory, and the report of a satisfactory calibration withheld unless the two agree within specified tolerances.

b. Specular Exclusion. The D54 and Match-Scan instruments currently echo a keyboard statement of whether the specular component is included or excluded, for later reference, but this is not related to the actual instrument configuration. An interlock should be provided so that the indication has real meaning.

C. Final Conclusion and Recommendation

We conclude that, although any of the instruments tested could provide NARADCOM's proposed objective textile acceptability measurements

with adequate precision, none of them is entirely satisfactory from all points of view, both objective and subjective. Thus some modifications of any of them will be required.

With appropriate modifications, any of the three instruments tested should be suitable for NARADCOM's requirements.

It is therefore recommended that the final selection of the instrument for ultimate use in the program be made by NARADCOM after consultations with the manufacturers regarding modifications.

This document reports research undertaken at the US Army Natick Research and Development Command and has been assigned No. NATICK/TR-77/14 in the series of reports approved for publication.

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TABLE 1a

SHORT-TERM REPEATABILITY OF NBS FILTERS

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT C

Sample		Instrument				
NBS-SRM Set No. 31	Type and Thickness	Kollmorgen* MS-2000 n=3	NARADCOM MS-2000 n=5	NARADCOM Hunter D54P-5 n=5	Diano* Match-Scan Forward Mode n=5	NARADCOM Match-Scan Reverse Mode n=5
2101	Selenium orange-red 2.61 mm	0.05±0.019	0.05±0.013	0.10±0.075	0.07±0.062	0.11±0.095
2102	Signal yellow 2.55 mm	0.07±0.006	0.04±0.021	0.03±0.019	0.06±0.043	0.04±0.014
2103	Sextant green 4.36 mm	0.09±0.018	0.06±0.038	0.04±0.019	0.05±0.030	0.05±0.024
2104	Cobalt blue 2.65 mm	0.08±0.048	0.12±0.101	0.02±0.013	0.06±0.042	0.03±0.011
2105	Selective neutral 2.94 mm	0.03±0.005	0.09±0.041	0.01±0.004	0.04±0.014	0.02±0.015

*Instrument on loan to The Rensselaer Color Measurement Laboratory for summer courses

TABLE 1b

SHORT-TERM REPEATABILITY STUDY ON NON-FLUORESCENT SAMPLES

COLOR DIFFERENCES IN CIELAB UNITS FOR ILL. D_{65}

Sample	Instrument			
BCRA Tile	Kollmorgen MS-2000	NARADCOM MS-2000	NARADCOM Hunter D54P-5	NARADCOM Match-Scan
Brown*	0.06±0.047	0.03±0.015	0.04±0.031	0.04±0.020
Pink**	0.05±0.019	0.03±0.010	0.02±0.011	0.04±0.009
Dark Blue	0.06±0.020	0.02±0.005	0.02±0.010	0.02±0.013
Medium Gray**	0.02±0.004	0.02±0.007	0.01±0.003	0.03±0.011
Light Gray**	0.03±0.009	0.02±0.007	0.01±0.003	0.03±0.015
Yellow*	0.04±0.007	0.05±0.020	0.04±0.016	0.04±0.014
Light Green*	0.02±0.012	0.02±0.006	0.02±0.010	0.02±0.007
Dark Green	0.05±0.025	0.03±0.013	0.05±0.022	0.03±0.012
Maroon	0.08±0.040	0.02±0.015	0.04±0.017	0.03±0.010
Greenish Blue	0.03±0.019	0.02±0.009	0.02±0.005	0.03±0.015
Medium Blue	0.02±0.020	0.01±0.004	0.01±0.007	0.02±0.012
Dark Gray	0.02±0.005	0.02±0.004	0.02±0.005	0.03±0.012

*Very slightly fluorescent
**Significantly fluorescent

TABLE 1c

SHORT-TERM REPEATABILITY ON FLUORESCENT SAMPLES

COLOR DIFFERENCES IN CIELAB UNITS FOR ILL. D_{65}

Sample Name	Instrument			
	Kollmorgen MS-2000	NARADCOM MS-2000	NARADCOM Hunter D54P-5	NARADCOM Match-Scan
Plastic White Scale #10	0.03±0.021	0.04±0.020	0.01±0.005	0.03±0.008
Horizon Blue	0.01±0.003	0.01±0.003	0.02±0.011	0.03±0.018
Rocket Red	0.07±0.068	0.06±0.039	0.08±0.055	0.05±0.022
Saturn Yellow	0.07±0.013	0.02±0.011	0.02±0.010	0.02±0.012
Blaze Orange	0.06±0.033	0.03±0.014	0.03±0.014	0.03±0.012
Signal Green	0.03±0.018	0.02±0.016	0.02±0.006	0.04±0.012

TABLE 2a

SHORT TERM AND LONG TERM REPEATABILITY STUDY ON BCRA TILES

COLOR DIFFERENCES IN CIELAB UNITS FOR ILL. D_{65}

BCRA Tile	Diano-Hardy II (n=5)	Week #1	Week #2	Week #3	Week #4	Week #5	Week #6	Week #7	Week #8	Long term Mean
Brown	0.17±0.106	0.10±0.040	0.09±0.055	0.10±0.044	0.12±0.039	0.11±0.041	0.12±0.045	0.08±0.027	0.12±0.031	0.06±0.021
		0.07±0.049	0.08±0.029	0.10±0.037	0.07±0.037	0.09±0.063	0.11±0.059	0.07±0.048	0.10±0.063	0.05±0.030
		0.11±0.055	0.21±0.126	0.21±0.151	0.23±0.095	0.23±0.091	0.21±0.114	0.19±0.148	0.22±0.143	0.07±0.018
		0.11±0.038	0.07±0.037	0.12±0.029	0.07±0.043	0.10±0.031	0.11±0.040	0.07±0.025	0.09±0.046	0.13±0.058
Pink	0.09±0.034	0.07±0.023	0.09±0.044	0.07±0.040	0.07±0.020	0.10±0.044	0.07±0.039	0.10±0.043	0.12±0.018	0.06±0.018
		0.05±0.011	0.06±0.009	0.05±0.019	0.08±0.019	0.07±0.023	0.09±0.028	0.09±0.016	0.07±0.012	0.04±0.022
		0.05±0.023	0.05±0.014	0.05±0.023	0.05±0.022	0.06±0.026	0.04±0.007	0.05±0.012	0.07±0.021	0.04±0.016
		0.09±0.029	0.08±0.031	0.09±0.024	0.08±0.035	0.07±0.041	0.09±0.036	0.08±0.022	0.08±0.030	0.09±0.041
Dark Blue	0.25±0.206	0.40±0.351	0.42±0.352	0.41±0.355	0.34±0.316	0.41±0.358	0.38±0.257	0.39±0.310	0.36±0.172	0.16±0.085
		0.37±0.301	0.35±0.218	0.38±0.315	0.36±0.269	0.39±0.246	0.30±0.222	0.34±0.273	0.38±0.316	0.09±0.037
		0.19±0.163	0.33±0.279	0.33±0.196	0.27±0.224	0.39±0.311	0.39±0.245	0.37±0.257	0.35±0.292	0.08±0.053
		0.29±0.189	0.34±0.254	0.28±0.153	0.32±0.223	0.31±0.209	0.29±0.150	0.36±0.203	0.30±0.168	0.09±0.046
Medium Gray	0.05±0.024	0.05±0.025	0.05±0.033	0.04±0.025	0.05±0.027	0.04±0.027	0.04±0.024	0.06±0.024	0.05±0.026	0.03±0.013
		0.03±0.023	0.04±0.026	0.04±0.031	0.05±0.038	0.04±0.025	0.04±0.011	0.04±0.030	0.04±0.021	0.02±0.011
		0.06±0.027	0.05±0.028	0.05±0.024	0.04±0.027	0.05±0.025	0.05±0.015	0.05±0.019	0.04±0.017	0.03±0.010
		0.03±0.023	0.04±0.028	0.03±0.010	0.03±0.016	0.04±0.026	0.02±0.010	0.03±0.016	0.03±0.008	0.02±0.008
Light Gray	0.11±0.046	0.17±0.082	0.11±0.071	0.09±0.047	0.08±0.050	0.11±0.071	0.12±0.057	0.11±0.055	0.09±0.042	0.04±0.016
		0.11±0.083	0.11±0.057	0.08±0.038	0.09±0.078	0.12±0.077	0.10±0.043	0.11±0.046	0.09±0.037	0.03±0.011
		0.10±0.054	0.10±0.029	0.08±0.039	0.10±0.034	0.07±0.023	0.10±0.033	0.09±0.039	0.10±0.040	0.03±0.007
		0.09±0.059	0.08±0.039	0.08±0.034	0.09±0.033	0.10±0.050	0.09±0.069	0.08±0.056	0.10±0.052	0.02±0.009
Yellow	0.17±0.054	0.16±0.087	0.15±0.118	0.12±0.083	0.15±0.121	0.16±0.097	0.14±0.111	0.17±0.119	0.12±0.078	0.05±0.031
		0.13±0.100	0.13±0.068	0.15±0.086	0.14±0.097	0.15±0.112	0.15±0.092	0.17±0.121	0.15±0.097	0.06±0.024
		0.14±0.081	0.12±0.081	0.11±0.085	0.13±0.093	0.12±0.085	0.13±0.086	0.13±0.093	0.14±0.092	0.06±0.034
		0.12±0.077	0.10±0.065	0.11±0.073	0.12±0.093	0.10±0.063	0.10±0.048	0.10±0.076	0.13±0.064	0.10±0.046

TABLE 2a (CONT'D.)

BCRA Tile	Diano-Hardy II (n=5)	Week #1	Week #2	Week #3	Week #4	Week #5	Week #6	Week #7	Week #8	Long term Mean
Light Green	0.07±0.016	0.11±0.059	0.07±0.034	0.07±0.020	0.07±0.023	0.05±0.012	0.33±0.262	0.07±0.019	0.08±0.041	0.06±0.053
		0.05±0.023	0.05±0.021	0.06±0.022	0.06±0.028	0.06±0.031	0.06±0.037	0.06±0.025	0.06±0.023	0.03±0.011
		0.06±0.016	0.06±0.018	0.04±0.024	0.04±0.017	0.05±0.023	0.05±0.029	0.06±0.024	0.06±0.024	0.03±0.015
		0.06±0.014	0.06±0.026	0.06±0.027	0.06±0.028	0.05±0.011	0.06±0.014	0.07±0.026	0.07±0.018	0.10±0.049
Dark Green	0.05±0.016	0.05±0.019	0.06±0.045	0.07±0.053	0.09±0.046	0.05±0.028	0.09±0.058	0.10±0.050	0.09±0.063	0.08±0.036
		0.05±0.024	0.05±0.014	0.03±0.012	0.05±0.028	0.06±0.024	0.04±0.022	0.05±0.028	0.07±0.043	0.05±0.025
		0.11±0.064	0.14±0.056	0.15±0.071	0.12±0.072	0.07±0.020	0.11±0.055	0.10±0.063	0.11±0.075	0.06±0.026
		0.08±0.022	0.05±0.030	0.04±0.019	0.06±0.012	0.06±0.020	0.07±0.029	0.05±0.025	0.05±0.015	0.07±0.032
Maroon	0.25±0.076	0.33±0.082	0.26±0.115	0.20±0.086	0.22±0.095	0.29±0.090	0.24±0.111	0.23±0.100	0.19±0.099	0.11±0.049
		0.17±0.117	0.28±0.157	0.27±0.113	0.25±0.067	0.17±0.073	0.19±0.052	0.18±0.135	0.17±0.116	0.10±0.053
		0.35±0.125	0.29±0.080	0.29±0.090	0.29±0.141	0.30±0.110	0.32±0.109	0.26±0.128	0.39±0.152	0.31±0.041
			(3.89±3.26)							(0.54±0.652)
		0.24±0.160	0.16±0.102	0.18±0.130	0.29±0.098	0.18±0.106	0.16±0.111	0.19±0.133	0.10±0.066	0.08±0.04
Greenish Blue	0.05±0.022	0.08±0.023	0.07±0.041	0.04±0.020	0.07±0.020	0.05±0.015	0.07±0.036	0.08±0.042	0.08±0.028	0.05±0.025
		0.07±0.019	0.07±0.016	0.07±0.021	0.07±0.022	0.06±0.021	0.06±0.015	0.08±0.021	0.08±0.028	0.04±0.021
		0.09±0.027	0.07±0.037	0.11±0.036	0.11±0.063	0.08±0.044	0.14±0.046	0.13±0.046	0.07±0.029	0.07±0.031
		0.07±0.011	0.04±0.019	0.05±0.008	0.05±0.019	0.05±0.011	0.06±0.022	0.06±0.010	0.07±0.023	0.08±0.021
Medium Blue	0.04±0.017	0.05±0.011	0.06±0.023	0.05±0.014	0.06±0.021	0.06±0.027	0.03±0.007	0.07±0.023	0.06±0.010	0.03±0.013
		0.04±0.015	0.05±0.012	0.04±0.009	0.05±0.020	0.04±0.014	0.05±0.013	0.05±0.013	0.05±0.013	0.02±0.011
		0.05±0.018	0.07±0.009	0.06±0.031	0.06±0.029	0.07±0.020	0.06±0.015	0.06±0.020	0.07±0.020	0.04±0.018
		0.05±0.025	0.05±0.024	0.04±0.013	0.05±0.012	0.06±0.022	0.05±0.027	0.05±0.023	0.05±0.023	0.03±0.017
Dark Gray	0.05±0.020	0.09±0.055	0.08±0.057	0.08±0.054	0.07±0.054	0.06±0.040	0.08±0.036	0.06±0.035	0.06±0.031	0.05±0.018
		0.07±0.048	0.08±0.046	0.09±0.050	0.09±0.059	0.08±0.048	0.09±0.047	0.08±0.059	0.08±0.044	0.03±0.012
		0.06±0.015	0.05±0.020	0.05±0.030	0.07±0.041	0.06±0.026	0.06±0.003	0.05±0.028	0.08±0.019	0.05±0.025
		0.06±0.024	0.05±0.018	0.05±0.024	0.06±0.030	0.07±0.027	0.05±0.029	0.06±0.036	0.08±0.030	0.02±0.006

For Weeks 1-8: First line represents results from Kollmorgen MS-2000.
Second line represents results from NARADCOM MS-2000.
Third line represents results from NARADCOM Hunter D54P-5.
Last line represents results from NARADCOM Match-Scan.

TABLE 2b

SHORT TERM AND LONG TERM REPEATABILITY STUDY ON TEXTILE STANDARDS

COLOR DIFFERENCES IN CIELAB UNITS FOR ILL D_{65}

Textile Standard	Column #1	Week #1	Week #2	Week #3	Week #4	Week #5	Week #6	Week #7	Week #8	Long term Mean
Ctn.	0.21±0.086	0.13±0.023	0.09±0.042	0.08±0.052	0.11±0.034	0.07±0.028	0.56±0.464	0.06±0.037	0.10±0.024	0.14±0.055
Duck	0.05±0.030	0.08±0.020	0.09±0.025	0.10±0.055	0.07±0.039	0.07±0.044	0.08±0.042	0.06±0.035	0.09±0.044	0.12±0.055
UTRD		0.09±0.041	0.12±0.061	0.11±0.046	0.13±0.063	0.13±0.054	0.11±0.054	0.11±0.026	0.11±0.067	0.09±0.057
		0.09±0.053	0.12±0.072	0.12±0.029	0.11±0.042	0.09±0.057	0.10±0.032	0.08±0.028	0.08±0.034	0.14±0.060
AG 44	0.10±0.064	0.06±0.027	0.05±0.030	0.03±0.015	0.03±0.025	0.04±0.017	0.05±0.035	0.06±0.023	0.08±0.042	0.05±0.020
Wl.	0.03±0.008	0.04±0.024	0.07±0.013	0.08±0.031	0.06±0.046	0.07±0.032	0.06±0.032	0.06±0.031	0.06±0.024	0.05±0.030
Serge		0.06±0.015	0.07±0.017	0.05±0.024	0.05±0.025	0.06±0.006	0.03±0.011	0.04±0.009	0.05±0.014	0.06±0.019
		0.07±0.024	0.05±0.035	0.06±0.040	0.06±0.017	0.07±0.022	0.07±0.035	0.08±0.024	0.07±0.042	0.05±0.013
Tan Wl	0.11±0.051	0.05±0.032	0.07±0.045	0.08±0.039	0.09±0.034	0.09±0.034	0.11±0.042	0.07±0.030	0.11±0.053	0.04±0.016
Cl. P/W	0.06±0.033	0.09±0.040	0.10±0.026	0.06±0.032	0.07±0.026	0.07±0.023	0.08±0.047	0.08±0.032	0.07±0.026	0.06±0.043
Trop.		0.05±0.016	0.06±0.037	0.07±0.005	0.06±0.024	0.06±0.029	0.06±0.016	0.07±0.019	0.08±0.031	0.05±0.026
		0.08±0.037	0.07±0.024	0.08±0.026	0.08±0.031	0.08±0.046	0.09±0.042	0.09±0.046	0.08±0.046	0.10±0.055
Bl. 150	0.13±0.087	0.08±0.041	0.11±0.071	0.10±0.072	0.09±0.068	0.12±0.025	0.13±0.088	0.12±0.044	0.10±0.065	0.07±0.021
Trop.	0.04±0.030	0.06±0.013	0.09±0.048	0.09±0.054	0.11±0.074	0.12±0.058	0.15±0.100	0.10±0.061	0.14±0.073	0.09±0.031
Wl.		0.09±0.041	0.10±0.025	0.11±0.044	0.10±0.068	0.09±0.016	0.07±0.030	0.10±0.035	0.11±0.039	0.04±0.038
		0.07±0.023	0.09±0.026	0.08±0.057	0.11±0.067	0.13±0.105	0.10±0.043	0.11±0.065	0.09±0.057	0.04±0.018
OG 108	0.17±0.082	0.07±0.022	0.12±0.038	0.15±0.039	0.09±0.030	0.12±0.036	0.17±0.048	0.10±0.055	0.17±0.070	0.09±0.028
Fl.	0.08±0.011	0.09±0.031	0.06±0.017	0.12±0.027	0.14±0.059	0.14±0.018	0.14±0.025	0.10±0.028	0.17±0.071	0.09±0.068
Shirt		0.07±0.043	0.07±0.031	0.10±0.035	0.11±0.038	0.08±0.034	0.09±0.059	0.08±0.035	0.07±0.039	0.06±0.027
		0.08±0.057	0.08±0.037	0.09±0.021	0.09±0.045	0.11±0.042	0.09±0.024	0.15±0.037	0.10±0.031	0.10±0.029

Column 1: Top line represents results from Diano-Hardy II (n=5).
Bottom line represents results from Hunter-D54 45°/0° (n=3).

Remaining Columns: First line represents results from Kollmorgen MS-2000.
Second line represents results from NARADCOM MS-2000.
Third line represents results from NARADCOM Hunter D54P-5.
Last line represents results from NARADCOM Match-Scan.

TABLE 2b (CONT'D.)

Textile Standard	Week #1	Week #2	Week #3	Week #4	Week #5	Week #6	Week #7	Week #8	Long term Mean
AG 344	0.06±0.031	0.14±0.061	0.08±0.063	0.11±0.044	0.15±0.071	0.14±0.045	0.19±0.070	0.10±0.030	0.07±0.027
P/W Gab.	0.07±0.052	0.07±0.066	0.06±0.020	0.08±0.038	0.08±0.039	0.06±0.019	0.11±0.048	0.12±0.046	0.07±0.044
	0.10±0.034	0.06±0.028	0.11±0.058	0.11±0.053	0.08±0.042	0.07±0.023	0.08±0.047	0.07±0.032	0.05±0.016
	0.15±0.068	0.10±0.053	0.07±0.033	0.07±0.019	0.07±0.040	0.09±0.041	0.09±0.059	0.07±0.041	0.09±0.040
OG 106	0.05±0.032	0.04±0.024	0.03±0.017	0.07±0.009	0.05±0.032	0.06±0.014	0.05±0.016	0.05±0.019	0.05±0.029
Ox./Nyl.	0.04±0.006	0.03±0.008	0.06±0.033	0.05±0.012	0.05±0.028	0.06±0.024	0.08±0.016	0.05±0.024	0.05±0.021
	0.12±0.079	0.15±0.095	0.12±0.060	0.13±0.091	0.14±0.070	0.12±0.060	0.11±0.034	0.12±0.076	0.09±0.052
	0.09±0.041	0.11±0.026	0.10±0.022	0.07±0.045	0.09±0.037	0.09±0.040	0.10±0.050	0.07±0.032	0.06±0.025
OG 107	0.07±0.033	0.12±0.041	0.13±0.063	0.11±0.051	0.09±0.039	0.10±0.034	0.10±0.025	0.11±0.040	0.06±0.029
Nyco Pop	0.07±0.030	0.08±0.025	0.09±0.037	0.09±0.029	0.08±0.026	0.08±0.036	0.05±0.026	0.10±0.040	0.06±0.031
	0.08±0.052	0.09±0.038	0.10±0.049	0.10±0.039	0.09±0.068	0.11±0.039	0.09±0.035	0.09±0.029	0.07±0.036
	0.12±0.062	0.09±0.019	0.12±0.032	0.10±0.032	0.07±0.030	0.10±0.027	0.08±0.028	0.11±0.027	0.09±0.044
OG 107	0.09±0.070	0.08±0.021	0.08±0.032	0.12±0.045	0.09±0.029	0.08±0.041	0.12±0.044	0.20±0.160	0.06±0.043
Ctn.	0.10±0.066	0.08±0.035	0.13±0.049	0.08±0.031	0.07±0.031	0.09±0.024	0.09±0.062	0.09±0.017	0.07±0.032
B'loon	0.11±0.030	0.07±0.050	0.11±0.025	0.08±0.045	0.08±0.024	0.13±0.022	0.13±0.046	0.21±0.045	0.10±0.045
	0.13±0.044	0.14±0.067	0.14±0.062	0.14±0.067	0.14±0.086	0.14±0.039	0.18±0.045	0.15±0.041	0.16±0.079
OG 107	0.08±0.038	0.08±0.037	0.08±0.068	0.13±0.072	0.11±0.061	0.10±0.045	0.09±0.038	0.09±0.040	0.08±0.032
Ctn. Sat.	0.05±0.034	0.06±0.019	0.09±0.039	0.08±0.045	0.11±0.030	0.09±0.040	0.10±0.056	0.08±0.028	0.07±0.044
	0.09±0.037	0.09±0.055	0.08±0.038	0.09±0.030	0.10±0.036	0.10±0.033	0.09±0.034	0.10±0.037	0.09±0.036
	0.06±0.023	0.13±0.069	0.10±0.037	0.07±0.025	0.08±0.029	0.12±0.032	0.07±0.031	0.06±0.024	0.16±0.062
OD7 Ctn.	0.12±0.102	0.18±0.064	0.16±0.092	0.20±0.085	0.19±0.083	0.14±0.080	0.16±0.096	0.13±0.055	0.19±0.149
Duck	0.14±0.120	0.17±0.097	0.17±0.067	0.20±0.116	0.12±0.071	0.16±0.113	0.11±0.088	0.09±0.061	0.22±0.128
MRWRP	0.10±0.051	0.10±0.034	0.09±0.033	0.11±0.060	0.07±0.053	0.12±0.076	0.13±0.050	0.13±0.072	0.09±0.045
	0.11±0.035	0.17±0.061	0.13±0.097	0.19±0.053	0.13±0.062	0.20±0.077	0.15±0.053	0.22±0.093	0.13±0.066
Tan 46	0.09±0.025	0.08±0.058	0.11±0.053	0.05±0.019	0.09±0.042	0.09±0.039	0.20±0.160	0.08±0.027	0.06±0.031
Ctn. Pop	0.07±0.023	0.09±0.032	0.09±0.039	0.10±0.023	0.09±0.044	0.08±0.016	0.08±0.018	0.08±0.015	0.05±0.026
	0.06±0.023	0.09±0.033	0.08±0.036	0.07±0.021	0.08±0.012	0.08±0.053	0.09±0.037	0.09±0.054	0.07±0.047
	0.09±0.040	0.07±0.019	0.07±0.023	0.07±0.032	0.08±0.044	0.07±0.028	0.08±0.036	0.08±0.050	0.09±0.022

TABLE 2b (CONT'D.)

Textile Standard	Week #1	Week #2	Week #3	Week #4	Week #5	Week #6	Week #7	Week #8	Long term Mean
AG 344	0.16±0.112	0.14±0.066	0.10±0.076	0.14±0.072	0.10±0.060	0.15±0.055	0.16±0.102	0.14±0.084	0.09±0.043
P/W Trop.	0.11±0.084	0.14±0.090	0.27±0.193	0.10±0.069	0.13±0.118	0.12±0.067	0.20±0.089	0.17±0.092	0.08±0.032
	0.16±0.062	0.16±0.060	0.17±0.068	0.13±0.075	0.15±0.063	0.12±0.054	0.12±0.055	0.12±0.046	0.05±0.018
	0.14±0.052	0.10±0.047	0.19±0.060	0.15±0.033	0.15±0.088	0.10±0.059	0.13±0.061	0.14±0.047	0.09±0.041
Tan 445	0.07±0.035	0.05±0.024	0.06±0.038	0.05±0.017	0.06±0.019	0.05±0.015	0.07±0.023	0.04±0.008	0.04±0.027
Twill	0.06±0.044	0.06±0.023	0.05±0.040	0.05±0.026	0.04±0.020	0.07±0.033	0.05±0.031	0.06±0.048	0.04±0.015
poly./cot.	0.04±0.024	0.03±0.015	0.02±0.008	0.02±0.011	0.03±0.014	0.02±0.009	0.02±0.011	0.02±0.007	0.15±0.037
	0.03±0.014	0.05±0.033	0.04±0.018	0.04±0.028	0.05±0.028	0.04±0.016	0.04±0.016	0.05±0.022	0.05±0.019
Blue 150	0.06±0.020	0.13±0.031	0.08±0.041	0.12±0.038	0.15±0.081	0.06±0.033	0.05±0.022	0.06±0.032	0.10±0.055
Wool	0.10±0.025	0.13±0.069	0.06±0.039	0.12±0.019	0.08±0.019	0.08±0.037	0.08±0.058	0.04±0.020	0.08±0.068
Gab.	0.09±0.045	0.07±0.023	0.09±0.012	0.10±0.051	0.08±0.039	0.10±0.029	0.06±0.028	0.07±0.041	0.07±0.029
	0.07±0.030	0.10±0.026	0.07±0.026	0.07±0.035	0.08±0.041	0.07±0.042	0.14±0.042	0.09±0.027	0.06±0.024
Blue 151	0.09±0.010	0.07±0.034	0.06±0.020	0.07±0.015	0.06±0.028	0.07±0.019	0.05±0.029	0.06±0.035	0.07±0.039
Wool	0.07±0.012	0.06±0.030	0.07±0.031	0.07±0.033	0.04±0.021	0.07±0.011	0.05±0.016	0.07±0.033	0.05±0.036
Trop.	0.06±0.004	0.05±0.020	0.04±0.018	0.05±0.025	0.08±0.032	0.06±0.027	0.06±0.014	0.04±0.006	0.05±0.028
	0.09±0.027	0.08±0.030	0.05±0.024	0.06±0.036	0.07±0.022	0.06±0.036	0.06±0.020	0.06±0.029	0.08±0.022

First line represents results from Kollmorgen MS-2000.
Second line represents results from NARADCOM MS-2000.
Third line represents results from NARADCOM Hunter D54P-5.
Last line represents results from NARADCOM Match-Scan.

TABLE 3

LONG TERM REPEATABILITY STUDY ON "CARRARA" GLASS TILES

COLOR DIFFERENCES IN CIELAB UNITS FOR ILL. D_{65}

Sample Name	Week #1	Week #2	Week #3	Week #4	Week #5	Week #6	Week #7	Week #8	Mean
Maroon	0.40	0.23	0.44	0.12	0.06	0.15	0.41	0.57	0.30±0.182
	0.15	0.10	0.05	0.03	0.05	0.07	0.17	0.05	0.08±0.052
	0.17	0.09	0.11	0.11	0.03	0.05	0.09	0.11	0.09±0.040
	0.15	0.14	0.15	0.06	0.10	0.16	0.14	0.09	0.13±0.036
Light Tan	0.03	0.06	0.07	0.10	0.10	0.02	0.11	0.09	0.07±0.033
	0.05	0.03	0.05	0.04	0.05	0.09	0.11	0.03	0.06±0.030
	0.03	0.04	0.04	0.02	0.03	0.01	0.03	0.02	0.03±0.009
	0.09	0.04	0.05	0.10	0.06	0.07	0.08	0.08	0.07±0.021
Dark Blue	0.07	0.07	0.04	0.02	0.09	0.04	0.06	0.08	0.06±0.023
	0.06	0.07	0.03	0.03	0.01	0.06	0.04	0.06	0.05±0.022
	0.02	0.01	0.04	0.06	0.03	0.03	0.05	0.04	0.03±0.015
	0.07	0.05	0.06	0.02	0.05	0.05	0.04	0.09	0.05±0.021
Light Green	0.06	0.05	0.11	0.09	0.09	0.05	0.05	0.09	0.07±0.025
	0.14	0.04	0.08	0.05	0.07	0.07	0.01	0.09	0.07±0.038
	0.02	0.05	0.02	0.03	0.05	0.01	0.03	0.02	0.03±0.013
	0.08	0.07	0.09	0.05	0.07	0.04	0.08	0.08	0.07±0.016
Red	0.46	0.11	0.14	0.09	0.08	0.18	0.30	0.17	0.19±0.128
	0.16	0.05	0.11	0.05	0.04	0.06	0.07	0.10	0.08±0.041
	0.27	0.09	0.22	0.14	0.10	0.33	0.20	0.23	0.20±0.083
	0.27	0.14	0.12	0.13	0.08	0.25	0.25	0.24	0.18±0.075
Light Blue	0.06	0.02	0.03	0.04	0.09	0.05	0.03	0.07	0.05±0.023
	0.08	0.03	0.10	0.06	0.14	0.08	0.07	0.07	0.08±0.032
	0.04	0.02	0.04	0.04	0.03	0.02	0.01	0.10	0.04±0.027
	0.09	0.06	0.04	0.07	0.06	0.05	0.03	0.05	0.06±0.020

TABLE 3 (CONT'D.)

Sample Name	Week #1	Week #2	Week #3	Week #4	Week #5	Week #6	Week #7	Week #8	Mean
Dark Tan	0.06	0.07	0.05	0.05	0.02	0.07	0.07	0.06	0.06±0.018
	0.07	0.03	0.01	0.03	0.03	0.05	0.05	0.05	0.04±0.018
	0.04	0.01	0.04	0.05	0.02	0.03	0.03	0.08	0.04±0.022
	0.06	0.06	0.07	0.02	0.05	0.03	0.07	0.08	0.05±0.022
Dark Green	0.04	0.08	0.16	0.11	0.05	0.13	0.06	0.06	0.09±0.043
	0.04	0.05	0.05	0.02	0.01	0.04	0.04	0.07	0.04±0.019
	0.03	0.08	0.06	0.04	0.08	0.05	0.14	0.03	0.06±0.037
	0.11	0.10	0.10	0.08	0.07	0.06	0.10	0.14	0.09±0.024
Dark Gray	0.07	0.05	0.08	0.01	0.04	0.07	0.10	0.06	0.06±0.027
	0.03	0.05	0.01	0.04	0.02	0.04	0.02	0.04	0.03±0.012
	0.01	0.04	0.04	0.04	0.01	0.02	0.02	0.03	0.03±0.013
	0.12	0.05	0.09	0.06	0.05	0.08	0.04	0.07	0.07±0.026
Light Gray	0.15	0.12	0.20	0.16	0.09	0.14	0.15	0.87	0.24±0.258
	0.12	0.04	0.06	0.05	0.10	0.08	0.03	0.05	0.07±0.031
	0.01	0.02	0.02	0.03	0.01	0.04	0.00	0.08	0.03±0.024
	0.12	0.07	0.05	0.03	0.03	0.05	0.05	0.04	0.05±0.028

First line respresents results from Kollmorgen MS-2000
Second line represents results from NARADCOM MS-2000
Third line represents results from NARADCOM Hunter D54P-5
Last line represents results from NARADCOM Match-Scan.

TABLE 4a

NARADCOM PORCELAIN ENAMEL TILE COLOR-DIFFERENCE STUDY

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

NARADCOM Porcelain Enamel Tile	Diano-Hardy II (n=3)	Kollmorgen MS-2000 (n=3)	NARADCOM MS-2000 (n=3)	NARADCOM Hunter D54P-5 (n=3)	NARADCOM Hunter D54P-5 (n=3)	NARADCOM Hunter D54P-5 (n=6)	NARADCOM Match-Scan (n=3)	Hunter D54 45°/0° (n=1)
Tan 325 97 Std.								
Tan 325 Thin 408	0.99±0.036	0.94±0.020	0.99±0.015	1.18±0.012	1.07±0.012	1.13±0.058	1.09±0.010	1.07
Tan 325 Full 102	0.57±0.021	0.61±0.032	0.62±0.017	0.55±0.010	0.57±0.01[illegible]	0.56±0.014	0.55±0.017	0.56
Tan M1 BS-130-S								
Tan M1 BS-157-HT	0.86±0.074	0.87±0.020	0.85±0.032	1.13±0.049	1.02±0.006	1.08±0.071	1.01±0.010	0.79
Tan M1 BS-104-LT	2.05±0.049	2.18±0.029	2.22±0.032	2.14±0.031	2.11±0.029	2.13±0.029	2.17±0.0[illegible]	1.98
Blue 150 BS-130-S								
Blue 150 BS-153-HT	1.20±0.051	1.41±0.040	1.69±0.053	1.28±0.087	1.23±0.050	1.29±0.081	1.37±0.026	1.26
Blue 150 BS-140-LT	1.24±0.064	1.34±0.026	1.25±0.035	1.33±0.087	1.24±0.052	1.25±0.070	1.29±0.030	1.47
Blue 151 BS-130-S								
Blue 151 BS-157-HT	0.90±0.115	0.94±0.066	0.84±0.046	1.17±0.020	1.32±0.128	1.25±0.116	0.86±0.091	0.83
Blue 151 BS-104-LT	0.77±0.026	0.81±0.010	0.83±0.023	0.71±0.087	0.55±0.010	0.63±0.104	0.68±0.051	0.79
SG 509 BS-156-S								
SG 509 BS-104-HT	0.99±0.015	1.14±0.029	1.13±0.010	1.09±0.010	1.16±0.032	1.12±0.042	1.18±0.013	1.02
SG 509 BS-130-LT	0.58±0.038	0.57±0.017	0.58±0.023	0.68±0.025	0.64±0.000	0.66±0.029	0.59±0.013	0.55
AG 44 BS-36-S								
AG 44 BS-55-HT	0.87±0.031	1.00±0.030	1.04±0.032	0.84±0.032	0.88±0.035	0.86±0.037	0.80±0.012	0.81
AG 44 BS-1-LT	0.88±0.000	1.00±0.006	0.93±0.006	1.06±0.031	0.92±0.050	0.99±0.087	0.80±0.010	0.93

TABLE 4b

PRECISION OF NARADCOM PORCELAIN ENAMEL COLOR-DIFFERENCE MEASUREMENT

NARADCOM Porcelain Enamel Tile Set	Mean Coefficient of Variation - Cv						
	Diano-Hardy II	Kollmorgen MS-2000	NARADCOM MS-2000	NARADCOM Hunter D54P-5 (n=3)	NARADCOM Hunter D54P-5 (n=3)	NARADCOM Hunter D54P-5 (n=6)	NARADCOM Match-Scan
Tan 325	0.037±0.000	0.037±0.022	0.021±0.009	0.014±0.006	0.014±0.004	0.038±0.019	0.020±0.015
Tan M1	0.055±0.044	0.018±0.007	0.026±0.016	0.029±0.020	0.010±0.006	0.040±0.037	0.008±0.002
Blue 150	0.047±0.006	0.024±0.006	0.030±0.002	0.067±0.002	0.041±0.001	0.059±0.005	0.021±0.003
Blue 151	0.081±0.066	0.041±0.041	0.041±0.019	0.070±0.075	0.058±0.056	0.13 ±0.005	0.090±0.022
SG 509	0.040±0.036	0.028±0.003	0.024±0.022	0.023±0.020	0.014±0.020	0.041±0.005	0.017±0.008
AG 44	0.018±0.025	0.018±0.017	0.019±0.017	0.034±0.006	0.047±0.010	0.065±0.032	0.014±0.002

TABLE 5a

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: AG 344 P/W GAB.

Instrument	Orientation	Thin Standard	Thin Blue	Thin Green	Thin Red	Full Standard	Full Blue	Full Green	Full Red
Kollmorgen MS-2000	0°	0.41	0.29	0.32	0.83	0.30	0.84	0.89	1.01
NARADCOM MS-2000	0°	0.35±0.068	0.26±0.064	0.26±0.020	0.87±0.110	0.30±0.047	0.84±0.108	0.97±0.101	1.06±0.127
	45°	0.35±0.051	0.27±0.032	0.16±0.030	0.69±0.042	0.32±0.042	0.68±0.086	0.78±0.090	0.86±0.025
	90°	0.46±0.045	0.34±0.026	0.21±0.105	0.93±0.084	0.39±0.012	0.84±0.102	0.93±0.051	1.15±0.006
NARADCOM ster D54P-5	0°	0.39±0.038	0.32±0.020	0.16±0.065	0.78±0.062	0.37±0.021	0.72±0.076	0.83±0.017	0.96±0.025
	45°	0.33±0.015	0.34±0.026	0.14±0.056	0.80±0.015	0.34±0.040	0.77±0.012	0.85±0.055	0.95±0.031
	90°	0.36±0.012	0.31±0.070	0.16±0.061	0.72±0.055	0.35±0.031	0.75±0.015	0.88±0.045	0.86±0.031
NARADCOM Match-Scan	0°	0.22±0.047	0.36±0.064	0.14±0.015	0.77±0.047	0.38±0.038	0.68±0.140	0.79±0.093	0.92±0.097
	45°	0.32±0.059	0.29±0.012	0.15±0.021	0.67±0.035	0.32±0.021	0.76±0.051	0.87±0.025	0.82±0.099
	90°	0.26±0.049	0.28±0.021	0.16±0.021	0.63±0.015	0.28±0.035	0.68±0.030	0.80±0.021	0.84±0.035

TABLE 5b

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: OG 106 Ox./Nyl.

Instrument	Orientation	Thin Standard	Thin Yellow	Thin Green	Thin Red	Full Standard	Full Yellow	Full Green	Full Red
Kollmorgen MS-2000	0°	3.06	4.52	4.15	3.10	0.72	1.97	1.61	0.74
NARADCOM MS-2000	0°	3.00±0.051	4.52±0.060	4.08±0.044	3.30±0.050	0.61±0.090	1.96±0.083	1.52±0.029	0.75±0.049
	45°	3.08±0.017	4.55±0.066	4.18±0.049	3.24±0.119	0.58±0.122	2.02±0.085	1.62±0.051	0.78±0.035
	90°	2.97±0.045	4.45±0.082	4.14±0.025	3.28±0.123	0.61±0.068	2.16±0.056	1.69±0.038	0.70±0.017
NARADCOM Hunter D54P-5	0°	2.82±0.021	4.45±0.012	3.79±0.112	3.29±0.091	0.70±0.044	2.12±0.015	1.55±0.042	0.62±0.042
	45°	2.87±0.079	4.44±0.090	3.73±0.119	3.35±0.085	0.69±0.140	2.11±0.080	1.62±0.032	0.68±0.017
	90°	2.81±0.086	4.46±0.044	3.80±0.049	3.33±0.068	0.71±0.115	2.14±0.111	1.54±0.012	0.61±0.012
NARADCOM Match-Scan	0°	2.64±0.060	4.25±0.057	3.80±0.096	3.34±0.090	0.90±0.030	2.54±0.035	1.98±0.032	0.72±0.050
	*45°	2.77±0.156	4.27±0.176	3.67±0.224	3.53±0.206	0.80±0.252	2.17±0.237	1.75±0.158	0.67±0.081
	90°	2.95±0.035	4.49±0.084	3.88±0.035	3.46±0.081	0.64±0.015	1.71±0.029	1.33±0.038	0.61±0.044

*Average of six measurements

TABLE 5c

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: OG 107 NYCO. POP

Instrument	Orientation	Thin Standard	Thin Yellow	Thin Green	Thin Red	Full Standard	Full Yellow	Full Green	Full Red
Kollmorgen MS-2000	0°	0.98	1.28	1.09	0.65	0.87	1.03	0.71	0.50
NARADCOM MS-2000	0°	0.96±0.040	1.40±0.046	0.97±0.050	0.67±0.049	1.20±0.049	1.01±0.035	0.67±0.071	0.43±0.046
	45°	0.98±0.067	1.48±0.107	0.99±0.103	0.67±0.010	1.05±0.055	1.06±0.106	0.75±0.040	0.41±0.086
	90°	1.05±0.055	1.45±0.032	0.98±0.067	0.70±0.055	1.00±0.045	1.09±0.015	0.68±0.061	0.44±0.114
NARADCOM Hunter D54P-5	0°	0.84±0.029	1.29±0.017	0.86±0.006	0.64±0.021	1.27±0.017	1.02±0.006	0.60±0.020	0.36±0.010
	45°	0.87±0.026	1.37±0.000	0.90±0.025	0.65±0.021	1.15±0.108	1.02±0.012	0.65±0.012	0.33±0.051
	90°	0.87±0.045	1.35±0.050	0.91±0.023	0.60±0.050	1.07±0.021	1.01±0.049	0.64±0.036	0.36±0.020
NARADCOM Match-Scan	0°	0.95±0.042	1.28±0.040	1.03±0.081	0.64±0.015	1.10±0.101	1.03±0.017	0.68±0.015	0.40±0.056
	*45°	0.91±0.081	1.41±0.097	0.88±0.088	0.67±0.034	1.12±0.080	1.05±0.049	0.64±0.031	0.42±0.078
	90°	1.08±0.021	1.56±0.036	1.00±0.036	0.72±0.045	0.90±0.111	1.11±0.006	0.73±0.081	0.45±0.038

*Average of six measurements

TABLE 5d

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: OG 107 CTN. B'LOON

Instrument	Orientation	Thin Standard	Thin Yellow	Thin Green	Thin Red	Full Standard	Full Yellow	Full Green	Full Red
Kollmorgen MS-2000	0°	1.26	0.41	1.22	0.88	1.31	1.07	1.95	1.70
NARADCOM MS-2000	0°	1.24±0.168	0.46±0.040	1.26±0.046	0.91±0.064	1.36±0.015	1.13±0.095	2.09±0.072	1.75±0.065
	45°	1.17±0.067	0.63±0.091	1.26±0.117	0.88±0.029	1.54±0.115	1.16±0.038	2.14±0.056	1.85±0.075
	90°	1.16±0.035	0.59±0.012	1.27±0.030	0.93±0.081	1.48±0.056	1.17±0.078	2.22±0.106	2.03±0.042
NARADCOM Hunter D54P-5	0°	1.39±0.017	0.77±0.021	1.26±0.017	1.14±0.025	1.75±0.015	1.69±0.000	2.46±0.026	2.11±0.015
	45°	1.38±0.070	0.72±0.072	1.29±0.059	1.15±0.067	1.72±0.038	1.65±0.036	2.40±0.150	2.09±0.049
	90°	1.31±0.070	0.74±0.055	1.29±0.021	1.10±0.080	1.74±0.031	1.64±0.023	2.38±0.102	2.15±0.070
NARADCOM Match-Scan	0°	1.37±0.072	0.93±0.046	1.41±0.083	1.38±0.036	1.66±0.241	1.69±0.085	2.56±0.082	2.31±0.142
	45°	1.33±0.040	0.94±0.057	1.41±0.006	1.37±0.017	1.63±0.117	1.71±0.017	2.59±0.040	2.24±0.072
	90°	1.12±0.093	0.75±0.015	1.36±0.031	1.19±0.061	1.49±0.017	1.57±0.104	2.41±0.065	2.10±0.053

TABLE 5e

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: OG 107 CTN. SAT.

Instrument	Orientation	Thin Standard	Thin Yellow	Thin Green	Thin Green	Thin Red	Full Standard	Full Yellow	Full Green	Full Red
Kollmorgen MS-2000	0	1.32	1.85	1.01	1.08	1.77	0.99	0.94	0.91	1.06
NARADCOM MS-2000	0°	1.32±0.076	1.83±0.035	1.07±0.040	1.09±0.040	1.73±0.021	1.05±0.021	1.02±0.032	0.98±0.079	1.12±0.058
	45°	1.46±0.078	1.86±0.055	1.05±0.050	1.05±0.084	1.76±0.075	1.02±0.137	0.98±0.060	0.89±0.057	1.10±0.049
	90°	1.28±0.081	1.84±0.006	1.06±0.036	1.18±0.025	1.66±0.032	1.07±0.025	0.94±0.029	0.98±0.081	1.04±0.053
NARADCOM Hunter D54P-5	0°	1.19±0.015	1.63±0.021	1.32±0.036	1.33±0.061	1.56±0.031	1.28±0.059	1.04±0.012	1.22±0.026	0.99±0.026
	45°	1.23±0.025	1.71±0.015	1.28±0.032	1.35±0.051	1.57±0.010	1.24±0.025	1.04±0.017	1.14±0.036	0.98±0.012
	90°	1.18±0.040	1.66±0.026	1.24±0.020	1.31±0.025	1.53±0.012	1.26±0.032	1.04±0.026	1.06±0.020	0.98±0.032
NARADCOM Match-Scan	0°	1.24±0.021	1.73±0.026	1.22±0.049	1.26±0.035	1.58±0.031	1.13±0.085	0.94±0.026	1.05±0.057	1.00±0.006
	45°	1.28±0.029	1.78±0.029	1.11±0.059	1.17±0.104	1.62±0.096	1.01±0.040	0.92±0.057	0.98±0.070	1.01±0.023
	90°	1.38±0.080	1.77±0.049	1.09±0.036	1.17±0.035	1.67±0.017	1.09±0.042	0.89±0.040	0.88±0.061	1.03±0.021

TABLE 5f

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: OD7 CTN. DUCK MRWRP

Instrument	Orientation	Thin Standard	Thin Yellow	Thin Green	Thin Red	Full Standard	Full Yellow
Kollmorgen MS-2000	0°	0.78	0.54	0.55	0.99	2.32	2.22
NARADCOM MS-2000	0°	0.76±0.085	0.59±0.076	0.62±0.068	0.88±0.000	2.33±0.162	2.47±0.006
	45°	0.70±0.036	0.51±0.059	0.57±0.010	0.92±0.059	2.39±0.083	2.34±0.046
	90°	0.80±0.139	0.46±0.050	0.47±0.072	1.02±0.081	2.26±0.117	2.26±0.118
NARADCOM Hunter D54P-5	0°	0.71±0.032	0.70±0.093	0.68±0.080	0.82±0.031	2.34±0.127	2.50±0.055
	45°	0.66±0.026	0.85±0.076	0.74±0.087	0.79±0.015	2.45±0.097	2.61±0.100
	90°	0.70±0.023	0.72±0.030	0.70±0.051	0.83±0.047	2.29±0.036	2.53±0.029
NARADCOM Match-Scan	0°	0.75±0.060	0.77±0.163	0.79±0.089	0.84±0.061	2.26±0.148	2.57±0.110
	45°	0.73±0.032	0.78±0.147	0.86±0.107	0.79±0.040	2.30±0.141	2.54±0.076
	90°	0.74±0.081	0.72±0.171	0.74±0.199	0.81±0.072	2.28±0.179	2.54±0.132

TABLE 5g

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: TAN 46 CTN. POP.

Instrument	Orientation	Thin Standard	Thin Blue	Thin Red	Full Standard	Full Yellow	Full Blue	Full Red
Kollmorgen MS-2000	0°	1.99	1.95	0.80	1.56	1.54	0.66	2.14
NARADCOM MS-2000	0°	1.92±0.061	2.01±0.044	0.87±0.067	1.65±0.065	1.55±0.012	0.64±0.044	2.25±0.038
	45°	2.07±0.125	2.04±0.038	0.77±0.081	1.64±0.010	1.51±0.035	0.59±0.032	2.09±0.075
	90°	1.99±0.055	1.94±0.093	0.86±0 045	1.58±0.067	1.54±0.092	0.54±0.015	2.21±0.060
NARADCOM Hunter D54P-5	0°	2.10±0.012	1.89±0.076	0.84±0.049	1.59±0.072	1.44±0.025	0.41±0.015	2.04±0.040
	45°	2.07±0.021	1.95±0.012	0.83±0.021	1.63±0.023	1.41±0.010	0.41±0.015	2.05±0.012
	90°	2.16±0.006	1.92±0.012	0.83±0.006	1.64±0.015	1.42±0.025	0.44±0.012	2.00±0.076
NARADCOM Match-Scan	0°	2.15±0.020	1.99±0.035	0.81±0.026	1.72±0.040	1.54±0.036	0.56±0.030	1.85±0.025
	*45°	2.05±0.080	1.95±0.080	0.87±0.052	1.74±0.084	1.59±0.087	0.56±0.045	1.98±0.073
	90°	2.09±0.047	1.92±0.025	0.80±0.042	1.75±0.065	1.64±0.020	0.56±0.035	2.14±0.055

*Average of six measurements

TABLE 5h

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: AG 344 P/W TROP.

Instrument	Orientation	Thin Standard	Thin Blue	Thin Green	Thin Red	Full Standard	Full Blue	Full Green	Full Red
Kollmorgen MS-20	0°	1.10	1.70	0.93	0.73	2.56	2.70	1.58	2.05
NARADCOM MS-2000	0°	0.99±0.042	1.51±0.148	0.92±0.074	0.71±0.120	2.37±0.093	2.60±0.108	1.44±0.081	1.86±0.068
	45°	1.02±0.093	1.45±0.112	0.84±0.031	0.66±0.101	2.32±0.103	2.58±0.095	1.39±0.060	1.95±0.039
	90°	0.98±0.032	1.41±0.115	0.89±0.040	0.71±0.021	2.39±0.055	2.64±0.046	1.46±0.066	1.94±0.083
NARADCOM Hunter D54P-5	0°	1.19±0.049	1.69±0.093	1.13±0.025	0.85±0.040	2.59±0.029	2.78±0.026	1.61±0.038	2.08±0.040
	45°	1.19±0.071	1.65±0.025	1.03±0.021	0.84±0.000	2.54±0.029	2.78±0.023	1.58±0.021	2.11±0.040
	90°	1.14±0.020	1.55±0.040	1.05±0.025	0.88±0.035	2.52±0.031	2.81±0.026	1.62±0.055	2.08±0.026
NARADCOM Match-Scan	0°	0.95±0.035	1.41±0.107	0.98±0.035	0.69±0.050	2.38±0.051	2.61±0.084	1.55±0.040	1.93±0.060
	45°	1.01±0.040	1.38±0.092	0.91±0.010	0.78±0.026	2.27±0.038	2.66±0.091	1.53±0.087	1.95±0.047
	90°	1.10±0.085	1.54±0.093	1.00±0.062	0.72±0.036	2.40±0.053	2.66±0.111	1.52±0.103	1.93±0.058

TABLE 51

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: TAN 445 TWILL POLY./COT.

Instrument	Orientation	Thin Standard	Thin Yellow	Thin Green	Thin Red	Full Standard	Full Yellow	Full Green	Full Red
Kollmorgen MS-2000	0°	2.23	2.15	0.15	0.97	0.65	0.38	0.13	0.35
NARADCOM MS-2000	0°	2.22±0.015	2.14±0.010	0.12±0.020	1.01±0.012	0.68±0.015	0.45±0.012	0.09±0.017	0.44±0.060
	45°	2.18±0.017	2.13±0.021	0.10±0.042	0.92±0.036	0.62±0.057	0.41±0.021	0.12±0.029	0.38±0.059
	90°	2.16±0.032	2.04±0.049	0.20±0.084	1.01±0.031	0.59±0.050	0.43±0.040	0.15±0.036	0.44±0.114
NARADCOM Hunter D54P-5	0°	1.99±0.017	1.99±0.015	0.32±0.010	0.89±0.026	0.35±0.032	0.16±0.012	0.13±0.006	0.93±0.015
	45°	1.95±0.026	1.96±0.025	0.34±0.025	0.92±0.025	0.37±0.021	0.17±0.023	0.15±0.006	0.97±0.012
	90°	1.99±0.023	2.00±0.026	0.35±0.010	0.87±0.015	0.38±0.015	0.21±0.017	0.14±0.040	0.89±0.020
NARADCOM Match-Scan	0°	2.07±0.031	1.96±0.015	0.33±0.025	0.79±0.025	0.40±0.015	0.22±0.006	0.13±0.030	0.95±0.021
	45°	2.04±0.035	1.97±0.020	0.34±0.055	0.73±0.015	0.35±0.017	0.20±0.025	0.22±0.032	0.95±0.044
	90°	1.92±0.051	2.01±0.012	0.33±0.049	0.77±0.036	0.37±0.046	0.22±0.026	0.18±0.075	0.79±0.015

TABLE 53

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: BLUE 150 GAB/WOOL

Instrument	Orientation	Thin Standard	Thin Blue	Thin Green	Thin Red	Full Standard	Full Blue	Full Green	Full Red
Kollmorgen MS-2000	0°	0.32	0.61	0.23	0.19	0.36	0.26	0.23	0.22
NARADCOM MS-2000	0°	0.32±0.040	0.55±0.032	0.24±0.053	0.30±0.035	0.28±0.070	0.21±0.036	0.38±0.035	0.18±0.029
	45°	0.32±0.036	0.56±0.025	0.24±0.032	0.27±0.015	0.22±0.010	0.12±0.030	0.33±0.021	0.14±0.045
	90°	0.34±0.036	0.57±0.051	0.23±0.023	0.21±0.062	0.21±0.045	0.13±0.032	0.31±0.025	0.17±0.045
NARADCOM Hunter D54P-5	0°	0.33±0.035	0.50±0.044	0.27±0.051	0.25±0.074	0.30±0.044	0.31±0.036	0.45±0.031	0.34±0.071
	45°	0.30±0.055	0.52±0.038	0.28±0.035	0.33±0.065	0.29±0.026	0.32±0.053	0.42±0.015	0.28±0.060
	90°	0.31±0.044	0.52±0.038	0.33±0.025	0.35±0.057	0.34±0.025	0.33±0.031	0.45±0.031	0.34±0.035
NARADCOM Match-Scan	0°	0.31±0.000	0.50±0.026	0.25±0.045	0.35±0.079	0.25±0.010	0.29±0.045	0.39±0.025	0.29±0.006
	45°	0.25±0.062	0.53±0.090	0.19±0.082	0.24±0.032	0.25±0.040	0.16±0.053	0.39±0.067	0.19±0.049
	90°	0.29±0.061	0.55±0.040	0.25±0.045	0.28±0.060	0.27±0.050	0.31±0.098	0.44±0.065	0.28±0.099

TABLE 5k

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: 007 CTN. DUCK UTRD

Instrument	Orientation	Thin Standard	Thin Yellow	Thin Green	Thin Red	Full Standard	Full Yellow	Full Green	Full Red
Kollmorgen MS-2000	0°	0.91	1.17	0.85	1.24	1.91	2.72	1.22	2.71
NARADCOM MS-2000	0°	1.05±0.029	1.20±0.062	0.87±0.087	1.22±0.084	2.02±0.035	2.66±0.111	1.18±0.160	2.82±0.117
	45°	0.87±0.036	1.19±0.111	0.91±0.064	1.24±0.015	2.00±0.017	2.66±0.090	1.18±0.031	2.79±0.040
	90°	0.88±0.035	1.23±0.006	0.99±0.026	1.24±0.042	1.96±0.103	2.65±0.031	1.11±0.047	2.82±0.021
NARADCOM Hunter D54P-5	0°	1.42±0.035	1.05±0.015	0.66±0.023	1.05±0.046	2.19±0.081	2.97±0.064	1.47±0.066	3.02±0.036
	45°	1.27±0.070	1.04±0.015	0.68±0.015	1.07±0.025	2.15±0.021	2.91±0.031	1.51±0.021	3.00±0.017
	90°	1.29±0.040	1.05±0.031	0.69±0.012	1.05±0.017	2.16±0.045	2.95±0.053	1.50±0.026	3.04±0.035
NARADCOM Match-Scan	0°	0.94±0.112	1.10±0.006	0.79±0.055	1.09±0.085	1.90±0.159	2.85±0.140	1.41±0.097	2.87±0.133
	45°	1.16±0.168	1.04±0.038	0.76±0.030	1.11±0.083	2.03±0.197	2.85±0.030	1.31±0.055	2.89±0.021
	90°	1.02±0.061	1.10±0.025	0.79±0.010	1.09±0.047	1.94±0.160	2.84±0.020	1.39±0.031	2.89±0.021

TABLE 51

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: AG 44 WL. SERGE

Instrument	Orientation	Thin Standard	Thin Blue	Thin Green	Thin Red	Full Standard	Full Blue	Full Green	Full Red
Kollmorgen MS-2000	0°	0.33	0.31	0.31	0.26	0.34	0.46	0.47	0.31
NARADCOM MS-2000	0°	0.32±0.032	0.34±0.031	0.34±0.040	0.29±0.050	0.31±0.012	0.47±0.006	0.52±0.047	0.31±0.032
	45°	0.36±0.038	0.31±0.015	0.33±0.017	0.27±0.006	0.29±0.012	0.43±0.078	0.47±0.059	0.26±0.070
	90°	0.32±0.040	0.33±0.031	0.33±0.015	0.28±0.051	0.31±0.067	0.51±0.032	0.53±0.081	0.30±0.052
NARADCOM Hunter D54P-5	0°	0.33±0.017	0.41±0.030	0.45±0.035	0.34±0.012	0.37±0.026	0.44±0.015	0.52±0.035	0.35±0.035
	45°	0.33±0.021	0.36±0.035	0.37±0.025	0.31±0.026	0.31±0.035	0.43±0.025	0.50±0.032	0.30±0.023
	90°	0.31±0.015	0.41±0.006	0.42±0.015	0.34±0.025	0.38±0.042	0.41±0.031	0.54±0.012	0.29±0.025
NARADCOM Match-Scan	0°	0.32±0.042	0.40±0.046	0.50±0.015	0.34±0.050	0.35±0.025	0.46±0.015	0.53±0.091	0.40±0.031
	45°	0.33±0.044	0.38±0.036	0.40±0.015	0.31±0.057	0.29±0.025	0.41±0.020	0.54±0.038	0.30±0.045
	90°	0.38±0.079	0.38±0.025	0.37±0.050	0.30±0.021	0.26±0.042	0.47±0.021	0.47±0.035	0.34±0.031

TABLE 5m

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: TAN M1 CL. P/W TROP.

Instrument	Orientation	Thin Standard	Thin Yellow	Thin Green	Thin Red	Full Standard	Full Yellow	Full Green	Full Red
Kollmorgen MS-2000	0°	0.74	1.60	0.33	0.54	0.26	0.56	0.44	0.50
NARADCOM MS-2000	0°	0.73±0.032	1.45±0.051	0.44±0.020	0.49±0.021	0.20±0.029	0.54±0.026	0.44±0.071	0.49±0.020
	45°	0.85±0.055	1.39±0.087	0.43±0.052	0.46±0.051	0.27±0.038	0.48±0.086	0.39±0.006	0.42±0.025
	90°	0.68±0.050	1.35±0.055	0.48±0.052	0.47±0.058	0.22±0.065	0.53±0.040	0.42±0.075	0.53±0.031
NARADCOM Hunter D54P-5	0°	0.54±0.049	1.35±0.021	0.37±0.026	0.45±0.012	0.19±0.021	0.56±0.025	0.41±0.010	0.50±0.030
	45°	0.50±0.015	1.40±0.036	0.41±0.020	0.38±0.031	0.21±0.045	0.55±0.056	0.44±0.015	0.47±0.015
	90°	0.52±0.053	1.37±0.062	0.39±0.061	0.41±0.081	0.24±0.040	0.58±0.091	0.45±0.086	0.50±0.029
NARADCOM Match-Scan	0°	0.57±0.082	1.21±0.092	0.38±0.015	0.38±0.064	0.29±0.051	0.70±0.079	0.49±0.020	0.60±0.110
	45°	0.50±0.056	1.39±0.036	0.34±0.021	0.37±0.055	0.30±0.065	0.62±0.049	0.53±0.036	0.58±0.026
	90°	0.59±0.026	1.45±0.051	0.36±0.035	0.39±0.006	0.31±0.029	0.54±0.067	0.43±0.025	0.48±0.050

TABLE 5n

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: BLUE 150 TROP. WL.

Instrument	Orientation	Thin Standard	Thin Blue	Thin Green	Thin Red	Full Standard	Full Blue	Full Green	Full Red
Kollmorgen MS-2000	0°	0.13	0.55	1.96	0.31	0.35	0.18	0.62	0.66
NARADCOM MS-2000	0°	0.32±0.074	0.64±0.031	0.58±0.081	0.50±0.133	0.47±0.106	0.29±0.071	0.66±0.085	0.71±0.125
	45°	0.21±0.031	0.60±0.093	0.45±0.038	0.39±0.042	0.42±0.069	0.17±0.057	0.62±0.142	0.67±0.052
	90°	0.26±0.017	0.66±0.078	0.55±0.020	0.35±0.064	0.47±0.042	0.21±0.012	0.72±0.102	0.64±0.060
NARADCOM Hunter D54P-5	0°	0.26±0.020	0.56±0.023	0.47±0.059	0.37±0.050	0.40±0.032	0.24±0.046	0.60±0.083	0.61±0.070
	45°	0.21±0.035	0.54±0.057	0.40±0.046	0.35±0.086	0.42±0.070	0.23±0.044	0.59±0.021	0.62±0.050
	90°	0.24±0.010	0.60±0.010	0.45±0.060	0.38±0.045	0.38±0.038	0.24±0.006	0.55±0.062	0.61±0.065
NARADCOM Match-Scan	0°	0.20±0.012	0.52±0.070	0.51±0.067	0.42±0.021	0.45±0.032	0.24±0.046	0.72±0.057	0.73±0.066
	45°	0.21±0.040	0.53±0.025	0.41±0.070	0.38±0.021	0.37±0.061	0.18±0.065	0.51±0.065	0.62±0.096
	90°	0.23±0.110	0.51±0.078	0.35±0.046	0.32±0.061	0.40±0.070	0.14±0.065	0.57±0.062	0.62±0.079

TABLE 50

TEXTILE ANGULAR ORIENTATION AND COLOR-DIFFERENCE STUDY

STANDARD NAME: OG 108 W/N FL. SHIRT

Instrument	Orientation	Thin Standard	Thin Yellow	Thin Green	Thin Red	Full Standard	Full Yellow	Full Green	Full Red
Kollmorgen MS-2000	0°	0.91	0.94	1.09	0.62	1.48	1.18	0.81	1.69
NARADCOM MS-2000	0°	1.03±0.119	1.15±0.136	1.22±0.086	0.70±0.168	1.24±0.442	1.13±0.185	0.70±0.182	1.62±0.162
	45°	1.05±0.056	1.18±0.075	1.25±0.035	0.54±0.050	1.30±0.244	1.05±0.049	0.66±0.095	1.63±0.140
	90°	0.93±0.078	1.13±0.085	1.11±0.183	0.55±0.032	1.28±0.036	1.26±0.100	0.75±0.144	1.75±0.075
NARADCOM Hunter D54P-5	0°	0.88±0.015	1.06±0.012	0.98±0.023	0.45±0.038	1.39±0.049	1.30±0.017	0.77±0.035	1.62±0.051
	45°	1.02±0.091	1.08±0.047	1.22±0.091	0.59±0.092	1.34±0.036	1.12±0.115	0.74±0.064	1.65±0.121
	90°	0.94±0.059	1.02±0.017	1.10±0.029	0.48±0.131	1.42±0.015	1.25±0.023	0.76±0.035	1.74±0.023
NARADCOM Match-Scan	0°	0.92±0.071	1.10±0.106	1.14±0.066	0.45±0.000	1.30±0.210	1.36±0.186	0.73±0.110	1.73±0.070
	45°	1.09±0.086	1.21±0.110	1.19±0.070	0.38±0.059	1.43±0.093	1.22±0.081	0.80±0.025	1.80±0.050
	90°	0.97±0.015	1.08±0.070	1.19±0.020	0.52±0.107	1.50±0.015	1.36±0.158	0.80±0.068	1.78±0.080

TABLE 5p

TEXTILE ANGULAR ORIENTATION AND COLOR DIFFERENCE-STUDY

STANDARD NAME: BLUE 151 WOOL TROP.

Instrument	Orientation	Thin Standard	Thin Blue	Thin Green	Thin Red	Full Standard	Full Blue	Full Green	Full Red
Kollmorgen MS-2000	0°	0.70	0.41	1.24	0.77	0.72	0.86	0.68	0.62
NARADCOM MS-2000	0°	0.71±0.015	0.31±0.026	1.24±0.031	0.88±0.089	0.65±0.035	0.81±0.046	0.63±0.023	0.48±0.030
	45°	0.70±0.015	0.37±0.075	1.24±0.015	0.90±0.050	0.67±0.042	0.85±0.062	0.54±0.082	0.51±0.081
	90°	0.74±0.015	0.36±0.080	1.24±0.032	0.80±0.044	0.67±0.057	0.83±0.056	0.46±0.036	0.51±0.070
NARADCOM Hunter D54P-5	0°	0.65±0.051	0.39±0.017	1.13±0.032	0.83±0.046	0.63±0.051	0.88±0.015	0.53±0.059	0.53±0.047
	45°	0.71±0.026	0.39±0.046	1.16±0.020	0.89±0.017	0.64±0.010	0.87±0.032	0.53±0.023	0.49±0.023
	90°	0.72±0.010	0.34±0.067	1.19±0.049	0.89±0.031	0.64±0.020	0.85±0.006	0.60±0.025	0.53±0.070
NARADCOM Match-Scan	0°	0.68±0.064	0.39±0.066	1.22±0.012	0.78±0.021	0.68±0.062	0.91±0.055	0.44±0.047	0.56±0.070
	45°	0.67±0.090	0.43±0.045	1.24±0.067	0.77±0.068	0.65±0.087	0.91±0.042	0.52±0.025	0.50±0.075
	90°	0.69±0.051	0.41±0.020	1.23±0.044	0.67±0.040	0.66±0.025	0.89±0.049	0.73±0.085	0.53±0.017

TABLE 5q

PRECISION OF COLOR-DIFFERENCE MEASUREMENT
0° ORIENTATION

Textile Set	Mean Coefficient of Variation		
	NARADCOM MS-2000	NARADCOM Hunter D54P-5	NARADCOM Match-Scan
AG 344 P/W Gab.	0.14 ±0.054	0.11 ±0.125	0.14 ±0.056
OG 106 Ox./Nyl.	0.041±0.047	0.029±0.025	0.028±0.018
OG 107 Nyco. Pop.	0.061±0.031	0.021±0.012	0.056±0.044
OG 107 Ctn. B'loon	0.062±0.040	0.013±0.009	0.059±0.037
OG 107 Ctn. Sat.	0.039±0.022	0.025±0.013	0.031±0.022
OD7 Ctn. Duck MRWRP	0.070±0.057	0.068±0.046	0.098±0.060
Tan 46 Ctn. Pop.	0.038±0.026	0.032±0.018	0.025±0.015
AG 344 P/W Trop.	0.070±0.046	0.029±0.017	0.041±0.021
Tan 445 Twill poly./cot.	0.070±0.079	0.038±0.031	0.056±0.074
Blue 150 Gab./Wool	0.15 ±0.064	0.15 ±0.075	0.092±0.083
OD7 Ctn. Duck UTRD	0.061±0.040	0.029±0.013	0.065±0.033
AG 44 Wl. Serge	0.091±0.048	0.064±0.022	0.097±0.052
Tan Ml Cl. P/W Trop.	0.070±0.051	0.055±0.034	0.12 ±0.059
Blue 150 Trop. Wl.	0.18 ±0.074	0.11 ±0.046	0.10 ±0.048
OG 108 W/N Fl. Shirt	0.18 ±0.098	0.033±0.024	0.090±0.057
Blue 151 Wool Trop.	0.055±0.028	0.063±0.032	0.085±0.052

TABLE 5r

PRECISION OF COLOR-DIFFERENCE MEASUREMENT

45° ORIENTATION

Textile Set	Mean Coefficient of Variation		
	NARADCOM MS-2000	NARADCOM Hunter D54P-5	NARADCOM Match-Scan
AG 344 P/W Gab.	0.11 ±0.049	0.096±0.127	0.088±0.055
OG 106 Ox./Nyl.	0.050±0.067	0.049±0.063	0.11 ±0.089*
OG 107 Nyco. Pop.	0.084±0.058	0.046±0.052	0.083±0.046*
OG 107 Ctn. B'loon	0.063±0.040	0.048±0.027	0.030±0.025
OG 107 Ctn. Sat.	0.062±0.031	0.020±0.010	0.048±0.025
OD7 Ctn. Duck MRWRP	0.051±0.037	0.057±0.038	0.083±0.061
Tan 46 Ctn. Pop.	0.043±0.033	0.015±0.012	0.051±0.015*
AG 344 P/W Trop.	0.066±0.040	0.018±0.018	0.035±0.019
Tan 445 Twill poly./cot.	0.13 ±0.143	0.046±0.042	0.072±0.062
Blue 150 Gab./Wool	0.13 ±0.104	0.14 ±0.065	0.24 ±0.102
OD7 Ctn. Duck UTRD	0.038±0.030	0.019±0.016	0.057±0.047
AG 44 Wl. Serge	0.11 ±0.085	0.078±0.019	0.10 ±0.051
Tan M1 Cl. P/W Trop.	0.094±0.053	0.071±0.064	0.095±0.063
Blue 150 Trop. Wl.	0.16 ±0.085	0.14 ±0.067	0.16 ±0.097
OG 108 Fl. Shirt	0.088±0.054	0.082±0.039	0.072±0.040
Blue 151 Wool Trop.	0.092±0.070	0.042±0.033	0.095±0.042

*Includes average of six measurements on all samples of textile set.

TABLE 5s

PRECISION OF COLOR-DIFFERENCE MEASUREMENT

90° ORIENTATION

Textile Set	Mean Coefficient of Variation		
	NARADCOM MS-2000	NARADCOM Hunter D54P-5	NARADCOM Match-Scan
AG 344 P/W Gab.	0.12 ±0.157	0.11 ±0.126	0.082±0.060
OG 106 Ox./Nyl.	0.033±0.033	0.039±0.052	0.026±0.020
OG 107 Nyco. Pop.	0.079±0.077	0.047±0.020	0.058±0.044
OG 107 Ctn. B'loon	0.042±0.024	0.041±0.025	0.038±0.025
OG 107 Ctn. Sat.	0.037±0.025	0.022±0.008	0.037±0.018
OD7 Ctn. Duck MRWRP	0.10 ±0.052	0.039±0.024	0.14 ±0.091
Tan 46 Ctn. Pop.	0.041±0.013	0.015±0.013	0.032±0.019
AG 344 P/W Trop.	0.040±0.020	0.022±0.011	0.051±0.019
Tan 445 Twill poly./cot.	0.15 ±0.146	0.062±0.093	0.11 ±0.134
Blue 150 Gab./Wool	0.18 ±0.089	0.099±0.035	0.21 ±0.090
OD7 Ctn. Duck UTRD	0.027±0.018	0.020±0.007	0.032±0.027
AG 44 Wl. Serge	0.13 ±0.060	0.058±0.033	0.11 ±0.056
Tan M1 Cl. P/W Trop.	0.12 ±0.083	0.13 ±0.059	0.071±0.039
Blue 150 Trop. Wl.	0.098±0.048	0.082±0.046	0.23 ±0.152
OG 108 W/N Fl. Shirt	0.091±0.058	0.058±0.089	0.070±0.066
Blue 151 Wool Trop.	0.086±0.066	0.062±0.047	0.057±0.028

TABLE 6

ACCURACY OF COLOR DIFFERENCE PERFORMANCE

COLOR DIFFERENCES IN FMC-2 UNITS FOR ILLUMINANT C

NARADCOM Porcelain Enamel Tile		Comparative Study Results	Diano-Hardy II (n=3)	Kollmorgen MS-2000 (n=3)	NARADCOM MS-2000 (n=3)	NARADCOM Hunter D54P-5 (n=3)	NARADCOM Hunter D54P-5 (n=3)	NARADCOM Hunter D54P-5 (n=6)	NARADCOM Match-Scan (n=3)
Standard	Sample								
Tan M1	Tan M1								
BS-130-S	BS-104-LT	4.25±0.090	4.13±0.110	4.33±0.075	4.28±0.075	4.32±0.095	4.20±0.071	4.26±0.099	4.30±0.021
Tan M1	Tan M1								
BS-157-HT	BS-104-LT	2.71±0.075	2.64±0.071	2.94±0.035	2.97±0.106	2.59±0.029	2.55±0.035	2.57±0.034	2.64±0.105
Blue 150	Blue 150								
BS-153-HT	BS-140-LT	6.52±0.093	5.14±0.053	5.69±0.070	6.09±0.146	5.26±0.343	5.05±0.164	5.16±0.267	5.47±0.051
Blue 150	Blue 150								
BS-130-S	BS-140-LT	3.65±0.494	2.79±0.168	3.03±0.055	3.03±0.244	2.82±0.211	2.62±0.136	2.72±0.193	2.78±0.029
Blue 151	Blue 151								
BS-157-HT	BS-130-S	1.63±0.081	1.76±0.150	1.53±0.0	1.24±0.101	1.96±0.107	2.21±0.223	2.09±0.207	1.47±0.160
Blue 151	Blue 151								
BS-104-LT	BS-157-HT	3.57±0.081	2.81±0.133	3.06±0.044	2.96±0.107	3.42±0.080	3.34±0.231	3.38±0.160	2.79±0.090
SG 509	SG 509								
BS-156-S	BS-130-LT	1.30±0.028	1.27±0.068	1.24±0.023	1.21±0.059	1.43±0.074	1.36±0.012	1.40±0.061	1.23±0.017
SG 509	SG 509								
BS-104-HT	BS-130-LT	3.51±0.050	3.33±0.042	3.62±0.057	3.62±0.049	3.73±0.096	3.82±0.046	3.78±0.084	3.66±0.040
AG 44	AG 44								
BS-36-S	BS-55-HT	2.03±0.029	1.93±0.081	2.18±0.047	2.23±0.065	1.88±0.105	1.95±0.087	1.91±0.095	1.74±0.025
AG 44	AG 44								
BS-1-LT	BS-55-HT	4.14±0.009	3.85±0.057	4.43±0.038	4.35±0.072	4.27±0.038	4.02±0.110	4.15±0.152	3.50±0.046

TABLE 7

ABSOLUTE ACCURACY OF COLOR MEASUREMENT OF NBS SRM 2101-2105

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT C

Filter	Description	Instrument				
NBS SRM Set No. 31	Type, Thickness	Kollmorgen* MS-2000 (n=3)	NARADCOM MS-2000 (n=5)	NARADCOM Hunter D54P-5 (n=5)	Diano Match-Scan* Forward Mode (n=5)	NARADCOM Match-Scan Reverse Mode (n=5)
2101	Selenium orange-red 2.61 mm	4.47±0.018	4.23±0.040	0.82±0.103	1.25±0.062	2.94±0.150
2102	Signal yellow 2.55 mm	1.16±0.063	0.87±0.028	0.74±0.035	0.42±0.040	0.60±0.026
2103	Sextant green 4.36 mm	2.72±0.056	2.52±0.068	2.25±0.042	1.20±0.036	2.43±0.027
2104	Cobalt blue 2.65 mm	2.33±0.109	1.56±0.169	2.91±0.026	0.73±0.073	0.97±0.028
2105	Selective Neutral 2.94 mm	0.88±0.024	0.81±0.031	0.71±0.004	0.22±0.033	0.39±0.027

*Instrument on loan to The Rensselaer Color Measurement Laboratory for summer courses

TABLE 8a

SHORT-TERM AND LONG-TERM ACCURACY STUDY ON BCRA TILES

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65 - SEX MODE

BCRA Tile	Week #1	Week #2	Week #3	Week #4	Week #5	Week #6	Week #7	Week #8	Grand Mean
Brown	0.36±0.080	0.40±0.108	0.43±0.105	0.39±0.120	0.42±0.114	0.33±0.124	0.36±0.072	0.32±0.127	0.37±0.040
	0.14±0.016	0.16±0.046	0.22±0.088	0.19±0.050	0.20±0.036	0.21±0.030	0.18±0.036	0.20±0.022	0.16±0.027
	2.17±0.106	2.07±0.244	2.09±0.257	2.19±0.263	2.14±0.223	2.11±0.232	2.19±0.250	2.21±0.261	2.14±0.053
	1.07±0.071	1.04±0.053	0.97±0.060	1.05±0.045	0.98±0.060	0.95±0.023	0.98±0.044	0.97±0.039	1.00±0.046
Pink	1.27±0.029	1.25±0.020	1.27±0.012	1.28±0.029	1.31±0.038	1.36±0.034	1.33±0.038	1.36±0.078	1.30±0.047
	1.27±0.034	1.27±0.033	1.26±0.019	1.29±0.042	1.28±0.030	1.30±0.037	1.29±0.045	1.26±0.039	1.27±0.015
	1.30±0.019	1.27±0.029	1.29±0.018	1.22±0.029	1.27±0.020	1.29±0.021	1.25±0.022	1.31±0.030	1.28±0.028
	0.19±0.021	0.22±0.059	0.24±0.055	0.25±0.046	0.30±0.059	0.30±0.055	0.32±0.064	0.32±0.062	0.26±0.055
Dark Blue	1.57±0.553	1.63±0.572	1.27±0.536	1.49±0.473	1.39±0.559	1.30±0.463	1.48±0.514	1.61±0.414	1.46±0.138
	1.76±0.503	1.72±0.439	1.75±0.518	1.66±0.474	1.56±0.492	1.54±0.396	1.70±0.464	1.58±0.525	1.56±0.086
	6.38±0.227	6.34±0.388	6.39±0.340	6.36±0.319	6.41±0.452	6.61±0.442	6.47±0.418	6.37±0.411	6.41±0.088
	3.49±0.297	3.50±0.355	3.54±0.279	3.52±0.328	3.68±0.334	3.62±0.292	3.61±0.389	3.43±0.316	3.54±0.083
Medium Gray	0.30±0.052	0.27±0.047	0.31±0.044	0.33±0.058	0.31±0.047	0.29±0.045	0.29±0.049	0.[illegible]050	0.30±0.019
	0.42±0.038	0.41±0.045	0.43±0.053	0.44±0.067	0.43±0.041	0.43±0.031	0.42±0.054	0.43±0.042	0.43±0.011
	0.61±0.061	0.63±0.057	0.65±0.049	0.63±0.045	0.63±0.055	0.66±0.052	0.66±0.052	0.68±0.048	0.64±0.023
	0.31±0.035	0.30±0.027	0.31±0.013	0.28±0.024	0.30±0.039	0.29±0.020	0.29±0.016	0.27±0.014	0.29±0.012
Light Gray	0.23±0.080	0.20±0.049	0.17±0.063	0.22±0.049	0.19±0.066	0.19±0.072	0.19±0.065	0.19±0.063	0.16±0.018
	0.26±0.042	0.24±0.053	0.21±0.027	0.25±0.032	0.25±0.061	0.25±0.033	0.26±0.043	0.23±0.057	0.22±0.014
	0.31±0.104	0.35±0.100	0.33±0.080	0.30±0.099	0.31±0.076	0.35±0.095	0.34±0.091	0.35±0.103	0.33±0.022
	0.14±0.087	0.12±0.082	0.11±0.084	0.13±0.075	0.15±0.110	0.16±0.109	0.13±0.094	0.14±0.106	0.13±0.015
Yellow	0.73±0.061	0.78±0.040	0.82±0.041	0.77±0.036	0.74±0.059	0.73±0.041	0.74±0.063	0.75±0.070	0.74±0.032
	0.54±0.049	0.50±0.029	0.51±0.045	0.53±0.067	0.55±0.071	0.61±0.073	0.63±0.095	0.56±0.054	0.53±0.046
	1.72±0.046	1.71±0.057	1.67±0.027	1.69±0.048	1.71±0.052	1.73±0.035	1.77±0.033	1.71±0.043	1.71±0.029
	1.00±0.090	1.02±0.082	1.13±0.091	1.12±0.124	1.27±0.077	1.26±0.102	1.26±0.106	1.24±0.106	1.16±0.113
Light Green	0.69±0.070	0.70±0.060	0.68±0.048	0.70±0.038	0.73±0.032	0.71±0.037	0.77±0.052	0.70±0.071	0.69±0.049
	0.79±0.028	0.77±0.038	0.75±0.037	0.79±0.034	0.79±0.049	0.78±0.045	0.77±0.026	0.78±0.046	0.78±0.015
	0.92±0.045	0.98±0.035	0.95±0.019	0.95±0.031	0.94±0.040	0.96±0.057	0.95±0.045	0.95±0.049	0.95±0.017
	0.47±0.047	0.50±0.047	0.54±0.036	0.57±0.056	0.66±0.045	0.63±0.052	0.67±0.049	0.66±0.062	0.59±0.076

TABLE 8a (CONT'D.)

BCRA Tile	Week #1	Week #2	Week #3	Week #4	Week #5	Week #6	Week #7	Week #8	Grand Mean
Dark Green	0.73±0.025	0.70±0.054	0.75±0.064	0.68±0.087	0.66±0.045	0.62±0.101	0.62±0.089	0.62±0.104	0.67±0.050
	0.51±0.038	0.38±0.024	0.36±0.014	0.37±0.031	0.41±0.046	0.45±0.035	0.37±0.042	0.48±0.068	0.41±0.054
	2.99±0.118	2.98±0.142	2.91±0.169	3.01±0.131	2.98±0.028	2.95±0.108	2.95±0.106	2.95±0.134	2.96±0.031
	1.15±0.046	1.10±0.035	1.10±0.018	1.11±0.027	1.07±0.029	1.04±0.027	1.05±0.037	1.03±0.021	1.08±0.039
Maroon	0.41±0.062	0.37±0.090	0.44±0.180	0.37±0.158	0.48±0.108	0.48±0.093	0.46±0.111	0.43±0.079	0.35±0.072
	0.43±0.117	0.56±0.266	0.61±0.172	0.57±0.192	0.51±0.119	0.54±0.089	0.54±0.126	0.52±0.083	0.50±0.051
	4.28±0.328	6.46±4.866 (4.29±0.304)	4.17±0.239	4.26±0.278	4.25±0.220	4.29±0.284	4.23±0.276	4.27±0.370	4.48±0.652 (4.26±0.043)
	1.88±0.105	1.98±0.064	1.94±0.058	1.94±0.106	1.95±0.073	1.93±0.079	1.92±0.071	1.93±0.040	1.92±0.030
Greenish Blue	0.18±0.073	0.18±0.063	0.26±0.029	0.22±0.051	0.23±0.028	0.26±0.054	0.22±0.087	0.24±0.057	0.22±0.034
	0.24±0.041	0.24±0.039	0.27±0.033	0.29±0.041	0.27±0.036	0.28±0.024	0.27±0.041	0.29±0.030	0.26±0.017
	1.74±0.087	1.79±0.060	1.74±0.113	1.81±0.124	1.90±0.084	1.81±0.143	1.85±0.141	1.81±0.066	1.80±0.054
	0.79±0.038	0.80±0.009	0.79±0.022	0.82±0.016	0.83±0.029	0.79±0.021	0.80±0.017	0.77±0.028	0.80±0.019
Medium Blue	0.29±0.027	0.31±0.049	0.33±0.046	0.30±0.052	0.31±0.055	0.29±0.016	0.29±0.047	0.26±0.044	0.29±0.021
	0.33±0.037	0.36±0.049	0.36±0.033	0.38±0.051	0.36±0.033	0.38±0.031	0.39±0.036	0.37±0.021	0.37±0.017
	1.17±0.055	1.15±0.069	1.18±0.045	1.15±0.063	1.14±0.059	1.17±0.044	1.16±0.049	1.21±0.061	1.17±0.022
	0.54±0.050	0.54±0.037	0.51±0.021	0.51±0.022	0.51±0.032	0.50±0.031	0.50±0.036	0.50±0.037	0.51±0.014
Dark Gray	0.22±0.037	0.22±0.032	0.20±0.031	0.19±0.023	0.18±0.008	0.17±0.021	0.17±0.024	0.17±0.031	0.17±0.017
	0.28±0.034	0.28±0.040	0.32±0.044	0.26±0.062	0.27±0.052	0.27±0.059	0.27±0.056	0.29±0.045	0.27±0.020
	1.52±0.043	1.50±0.058	1.49±0.045	1.50±0.077	1.49±0.054	1.55±0.050	1.54±0.044	1.54±0.087	1.52±0.024
	0.81±0.054	0.79±0.042	0.80±0.047	0.79±0.056	0.77±0.062	0.80±0.054	0.77±0.065	0.76±0.061	0.78±0.017

First line represents results from Kollmorgen MS-2000.
Second line represents results from NARADCOM MS-2000.
Third line represents results from NARADCOM Hunter D54P-5.
Fourth line represents results from NARADCOM Match-Scan.

TABLE 8b

SHORT-TERM AND DAY TO DAY ABSOLUTE ACCURACY STUDY

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65 - SIN MODE

BCRA Tile	Day #1	Day #2	Day #3	Day #4	Day #5	Grand Mean
Brown	0.16±0.063	0.15±0.061	0.18±0.035	0.26±0.129	0.17±0.066	0.12±0.051
	0.54±0.080	0.61±0.103	0.65±0.127	0.64±0.101	0.64±0.099	0.61±0.044
Pink	0.78±0.021	0.79±0.026	0.82±0.031	0.81±0.022	0.78±0.046	0.80±0.018
	0.25±0.022	0.29±0.037	0.32±0.044	0.37±0.066	0.33±0.038	0.31±0.047
Dark	1.04±0.291	1.03±0.295	1.03±0.314	1.02±0.325	0.97±0.276	1.02±0.026
Blue	0.24±0.051	0.24±0.074	0.29±0.099	0.30±0.149	0.29±0.099	0.22±0.024
Medium	0.31±0.016	0.27±0.022	0.26±0.028	0.28±0.024	0.27±0.022	0.28±0.018
Gray	0.15±0.016	0.15±0.018	0.14±0.015	0.15±0.008	0.15±0.019	0.15±0.005
Light	0.29±0.081	0.21±0.057	0.20±0.075	0.20±0.072	0.20±0.083	0.22±0.040
Gray	0.13±0.011	0.12±0.029	0.12±0.020	0.13±0.039	0.12±0.036	0.12±0.004
Yellow	0.57±0.076	0.52±0.125	0.50±0.125	0.48±0.120	0.50±0.120	0.50±0.033
	0.53±0.075	0.65±0.122	0.64±0.081	0.68±0.086	0.68±0.110	0.63±0.062
Light	0.27±0.036	0.27±0.031	0.29±0.027	0.29±0.034	0.30±0.038	0.28±0.015
Green	0.32±0.024	0.32±0.028	0.31±0.035	0.35±0.017	0.34±0.029	0.32±0.016
Dark	0.49±0.070	0.49±0.049	0.51±0.051	0.50±0.047	0.48±0.044	0.49±0.013
Green	0.06±0.013	0.09±0.025	0.12±0.044	0.09±0.020	0.13±0.058	0.09±0.027
Maroon	0.46±0.252	0.43±0.180	0.45±0.248	0.46±0.217	0.41±0.166	0.43±0.023
	0.37±0.100	0.36±0.088	0.43±0.128	0.53±0.129	0.44±0.089	0.42±0.067
Greenish	0.17±0.033	0.15±0.028	0.16±0.038	0.17±0.043	0.18±0.036	0.16±0.011
Blue	0.24±0.031	0.24±0.035	0.23±0.042	0.24±0.025	0.22±0.032	0.23±0.011
Medium	0.32±0.034	0.36±0.181	0.26±0.036	0.28±0.038	0.27±0.035	0.29±0.030
Blue	0.17±0.016	0.17±0.029	0.18±0.024	0.20±0.008	0.18±0.027	0.18±0.016
Dark	0.09±0.019	0.11±0.011	0.08±0.013	0.07±0.007	0.07±0.006	0.08±0.018
Gray	0.13±0.018	0.14±0.024	0.12±0.014	0.12±0.029	0.11±0.018	0.12±0.008

Top line represents results from NARADCOM Hunter D54P-5.
Bottom line represents results from NARADCOM Match-Scan.

TABLE 8c

SHORT-TERM ABSOLUTE ACCURACY STUDY - SIN MODE

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

BCRA Tile	Diano-Hardy II (n=5)	Measurement #1	Measurement #2	Grand Mean
Brown	0.63±0.165	1.10±0.059	1.09±0.094	1.09±0.011
		0.64±0.049	0.65±0.040	0.64±0.010
		0.18±0.052	0.21±0.041	0.16±0.003
		0.45±0.080	0.46±0.079	0.44±0.014
Pink	0.46±0.057	1.31±0.038	1.33±0.026	1.32±0.017
		1.28±0.026	1.31±0.036	1.29±0.021
		0.83±0.031	0.86±0.032	0.84±0.021
		0.14±0.072	0.14±0.056	0.13±0.005
Dark Blue	0.59±0.258	1.27±0.070	1.26±0.043	1.23±0.002
		1.03±0.085	1.03±0.088	1.00±0.001
		0.81±0.197	0.79±0.233	0.80±0.010
		0.27±0.161	0.24±0.150	0.16±0.006
Medium Gray	0.20±0.026	0.63±0.029	0.64±0.024	0.63±0.014
		0.67±0.049	0.66±0.043	0.66±0.014
		0.17±0.014	0.18±0.014	0.17±0.001
		0.17±0.020	0.15±0.030	0.16±0.014
Light Gray	0.18±0.079	0.24±0.052	0.24±0.025	0.23±0.001
		0.28±0.023	0.26±0.018	0.26±0.001
		0.16±0.054	0.16±0.057	0.15±0.001
		0.10±0.020	0.09±0.027	0.09±0.005
Yellow	0.73±0.078	1.35±0.042	1.35±0.059	1.34±0.001
		0.89±0.081	0.93±0.053	0.90±0.030
		0.56±0.132	0.62±0.119	0.59±0.042
		0.58±0.112	0.53±0.117	0.54±0.049
Light Green	0.47±0.064	0.73±0.043	0.73±0.032	0.73±0.003
		0.78±0.032	0.78±0.026	0.78±0.008
		0.30±0.035	0.32±0.010	0.31±0.020
		0.25±0.038	0.23±0.031	0.24±0.021
Dark Green	0.46±0.040	1.32±0.052	1.35±0.055	1.34±0.022
		1.00±0.034	1.01±0.029	1.01±0.009
		0.59±0.033	0.60±0.053	0.59±0.009
		0.09±0.015	0.06±0.013	0.06±0.028

TABLE 8c (CONT'D.)

BCRA Tile	Diano-Hardy II (n=5)	Measurement #1	Measurement #2	Grand Mean
Maroon	0.58±0.091	1.10±0.046	1.09±0.039	1.08±0.000
		0.84±0.046	0.85±0.047	0.83±0.002
		0.36±0.083	0.33±0.114	0.33±0.025
		0.40±0.126	0.42±0.141	0.40±0.017
Greenish Blue	0.31±0.025	1.01±0.031	1.01±0.040	1.01±0.004
		0.90±0.045	0.91±0.038	0.90±0.008
		0.15±0.043	0.12±0.051	0.13±0.027
		0.17±0.022	0.14±0.007	0.14±0.020
Medium Blue	0.19±0.028	0.85±0.020	0.86±0.038	0.86±0.004
		0.79±0.010	0.82±0.019	0.80±0.020
		0.18±0.031	0.17±0.027	0.18±0.012
		0.16±0.025	0.15±0.015	0.15±0.002
Dark Gray	0.36±0.019	0.91±0.019	0.92±0.022	0.91±0.007
		0.84±0.016	0.83±0.016	0.83±0.010
		0.10±0.014	0.11±0.024	0.10±0.011
		0.15±0.024	0.14±0.027	0.14±0.005

First line represents results from Kollmorgen MS-2000.
Second line represents results from NARADCOM MS-2000.
Third line represents results from NARADCOM Hunter D54P-5.
Fourth line represents results from NARADCOM Match-Scan.

TABLE 9a

SENSITIVITY TO TEXTILE ORIENTATION

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

THIN STANDARD

Thin Standard Name	NARADCOM MS-2000		NARADCOM Hunter D54P-5		NARADCOM Match-Scan	
	45°	90°	45°	90°	45°	90°
AG 344 P/W Gab.	0.05±0.012	0.11±0.015	0.06±0.021	0.08±0.030	0.29±0.035	0.23±0.040
OG 106 Ox./Nyl.	0.09±0.012	0.26±0.015	0.21±0.006	0.20±0.017	1.03±0.144	1.20±0.044
OG 107 Nyco. Pop.	0.07±0.006	0.14±0.020	0.03±0.015	0.06±0.021	0.09±0.026	0.27±0.071
OG 107 Ctn. B'loon	0.06±0.020	0.05±0.029	0.08±0.040	0.09±0.065	0.21±0.031	0.32±0.015
OG 107 Ctn. Sat.	0.08±0.038	0.26±0.017	0.03±0.012	0.03±0.017	0.13±0.025	0.46±0.108
OD7 Ctn. Duck MRWRP	0.08±0.023	0.05±0.021	0.06±0.023	0.06±0.036	0.09±0.025	0.14±0.010
Tan 46 Ctn. Pop.	0.06±0.021	0.08±0.025	0.03±0.017	0.03±0.012	0.10±0.026	0.15±0.021
AG 344 P/W Trop.	0.07±0.026	0.08±0.031	0.07±0.006	0.09±0.025	0.10±.049	0.12±0.071
Tan 445 Twill poly./cot.	0.10±0.049	0.17±0.015	0.04±0.012	0.07±0.025	0.14±0.021	0.20±0.012
Blue 150 Gab./Wool	0.07±0.006	0.08±0.017	0.08±0.017	0.07±0.036	0.20±0.050	0.24±0.035
OD7 Ctn. Duck UTRD	0.04±0.015	0.06±0.046	0.02±0.006	0.05±0.035	0.18±0.098	0.25±0.076
AG 44 Wl. Serge	0.04±0.020	0.07±0.025	0.03±0.010	0.04±0.015	0.13±0.065	0.18±0.058
Tan M1 Cl. P/W Trop.	0.05±0.006	0.08±0.006	0.08±0.010	0.10±0.015	0.19±0.020	0.21±0.017
Blue 150 Trop. Wl.	0.06±0.040	0.05±0.012	0.03±0.010	0.03±0.006	0.11±0.093	0.09±0.072
OG 108 W/N Fl. Shirt	0.07±0.017	0.10±0.052	0.03±0.017	0.08±0.029	0.09±0.015	0.12±0.036
Blue 151 Wool Trop.	0.06±0.045	0.10±0.015	0.02±0.015	0.05±0.010	0.08±0.015	0.15±0.039

TABLE 9b

SENSITIVITY TO TEXTILE ORIENTATION

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

FULL STANDARD

Full Standard Name	NARADCOM MS-2000 45°	NARADCOM MS-2000 90°	NARADCOM Hunter D54P-5 45°	NARADCOM Hunter D54P-5 90°	NARADCOM Match-Scan 45°	NARADCOM Match-Scan 90°
AG 344 P/W Gab.	0.07±0.040	0.09±0.015	0.10±0.031	0.13±0.032	0.24±0.026	0.28±0.040
OG 106 Ox./Nyl.	0.14±0.035	0.34±0.092	0.23±0.012	0.18±0.045	1.27±0.148	1.56±0.078
OG 107 Nyco. Pop.	0.07±0.035	0.22±0.035	0.11±0.030	0.14±0.031	0.18±0.038	0.55±0.070
OG 107 Ctn. B'loon	0.05±0.026	0.05±0.012	0.08±0.044	0.12±0.006	0.20±0.061	0.31±0.049
OG 107 Ctn. Sat.	0.14±0.023	0.31±0.025	0.06±0.035	0.07±0.032	0.18±0.065	0.64±0.107
OD7 Ctn. Duck MRWRP	0.06±0.006	0.06±0.000	0.03±0.000	0.04±0.007	0.13±0.010	0.17±0.044
Tan 46 Ctn. Pop.	0.06±0.021	0.10±0.006	0.02±0.000	0.02±0.015	0.15±0.031	0.16±0.015
AG 344 P/W Trop.	0.06±0.025	0.06±0.023	0.05±0.015	0.08±0.012	0.19±0.025	0.16±0.006
Tan 445 Twill poly./cot.	0.14±0.061	0.19±0.021	0.05±0.010	0.04±0.020	0.17±0.087	0.20±0.064
Blue 150 Gab./Wool	0.09±0.042	0.08±0.042	0.05±0.023	0.05±0.000	0.10±0.035	0.18±0.100
OD7 Ctn. Duck UTRD	0.03±0.015	0.03±0.006	0.03±0.017	0.05±0.000	0.32±0.127	0.34±0.078
AG 44 Wl. Serge	0.07±0.030	0.06±0.038	0.03±0.017	0.05±0.021	0.20±0.035	0.21±0.058
Tan M1 Cl. P/W Trop.	0.10±0.025	0.08±0.029	0.05±0.040	0.08±0.053	0.21±0.038	0.20±0.006
Blue 150 Trop. Wl.	0.04±0.012	0.06±0.030	0.04±0.026	0.04±0.025	0.10±0.032	0.12±0.038
OG 108 W/N Fl. Shirt	0.03±0.010	0.07±0.038	0.07±0.026	0.08±0.036	0.12±0.067	0.17±0.042
Blue 151 Wool Trop.	0.04±0.015	0.06±0.021	0.04±0.015	0.06±0.021	0.08±0.026	0.11±0.006

TABLE 9c

SENSITIVITY TO TEXTILE ORIENTATION

INSTRUMENT: HUNTER D54 45°/0°

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

Textile Standard	90° Rotation
OD7 Ctn. Duck UTRD	0.36
AG 44 Wl. Serge	0.32
Tan Ml Cl. P/W Trop.	1.05
Blue 150 Trop. Wl.	0.69
OG 108 W/N Fl. Shirt	0.19

TABLE 10a

REPEATABILITY IN SIN MODE VS. SEX MODE

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

Sample Group	Diano-Hardy II		Kollmorgen MS-2000		NARADCOM MS-2000		NARADCOM Hunter D54P-5		NARADCOM Match-Scan	
	$\overline{\Delta E^*_{SIN}}$	$\overline{\Delta E^*_{SEX}}$	$\overline{\Delta E^*_{SIN}}$	$\overline{\Delta E^*_{SEX}}$	$\overline{\Delta E^*_{SIN}}$	$\overline{\Delta E^*_{SEX}}$	$\overline{\Delta E^*_{SIN}}$	$\overline{\Delta E^*_{SEX}}$	$\overline{\Delta E^*_{SIN}}$	$\overline{\Delta E^*_{SEX}}$
NARADCOM Porcelain Enamels N=6	0.05±0.012	0.06±0.034	0.02±0.008	0.02±0.008	0.03±0.013	0.03±0.012	0.02±0.012	0.03±0.017	0.02±0.009	0.02±0.008
Johnson Gray Tiles N=7	0.04±0.022	0.05±0.043	0.03±0.009	0.04±0.017	0.03±0.008	0.04±0.021	0.02±0.011	0.06±0.084	0.02±0.010	0.03±0.011
Ceramic Tiles N=8			0.04±0.049	0.08±0.137	0.03±0.015	0.09±0.160	0.03±0.018	0.08±0.127	0.03±0.028	0.03±0.010
Davis-Bruning Porcelain Enamels N=4	0.06±0.021	0.08±0.039	0.17±0.232	0.07±0.046	0.02±0.010	0.03±0.013	0.08±0.051	0.06±0.035	0.03±0.005	0.04±0.030
"Carrara" Glasses N=4			0.03±0.005	0.04±0.029	0.03±0.013	0.03±0.014	0.02±0.006	0.02±0.014	0.02±0.005	0.03±0.010
Painted Panels N=2	0.05±0.014	0.04±0.014	0.04±0.021	0.03±0.007	0.02±0.007	0.03±0.007	0.02±0.007	0.04±0.014	0.03±0.007	0.02±0.007

N = Number of samples in each group

TABLE 10b

DIFFERENCES IN REFLECTANCE FACTORS BETWEEN SIN AND SEX MODES

Sample Group	Sample Name	Diano-Hardy II	Kollmorgen MS-2000	NARADCOM MS-2000	NARADCOM Hunter D54P-5	NARADCOM Match-Scan
NARADCOM Porcelain Enamels	E4	4.16±0.057	5.00±0.077	4.62±0.026	3.45±0.083	4.09±0.046
	E9	4.95±0.107	5.92±0.144	5.61±0.053	4.15±0.066	4.79±0.060
	E11	5.26±0.112	6.30±0.146	5.94±0.028	4.41±0.039	5.03±0.035
	E14	4.78±0.113	5.69±0.106	5.41±0.041	3.97±0.083	4.61±0.049
	E17	5.14±0.114	6.11±0.115	5.86±0.053	4.34±0.079	4.98±0.068
	E19	3.98±0.119	4.66±0.109	4.41±0.105	3.19±0.115	3.86±0.076
Painted Panels	L1	2.76±0.053	3.24±0.090	3.14±0.104	1.84±0.019	2.72±0.082
	B1	2.90±0.034	3.50±0.064	3.34±0.101	1.91±0.040	2.77±0.032
Johnson Gray Tiles	J1	3.97±0.041	4.78±0.050	4.47±0.064	3.42±0.043	4.04±0.050
	J2	4.33±0.097	4.98±0.107	4.90±0.148	3.70±0.103	4.26±0.068
	J3	4.35±0.092	5.06±0.092	4.95±0.058	3.67±0.110	4.26±0.079
	J4	4.30±0.085	5.05±0.071	4.85±0.048	3.59±0.095	4.19±0.067
	J5	4.20±0.053	4.85±0.045	4.76±0.066	3.68±0.034	4.10±0.018
	J6	4.15±0.049	4.95±0.029	4.85±0.027	3.84±0.074	4.18±0.041
	J7	4.04±0.065	4.65±0.034	4.57±0.053	3.70±0.069	3.99±0.027
Davis-Bruning Porcelain Enamels	Po-1	3.54±0.075	4.08±0.133	4.02±0.119	2.95±0.085	3.62±0.106
	Po-2	3.55±0.151	4.14±0.204	4.03±0.218	2.90±0.065	3.49±0.200
	Po-3	2.92±0.178	3.37±0.221	3.36±0.209	2.60±0.094	2.98±0.171
	Po-4	4.22±0.144	4.66±0.244	4.16±0.316	3.41±0.122	4.10±0.141
Ceramic Tiles	C3		5.32±0.091	5.05±0.053	3.69±0.112	4.44±0.076
	C6		5.22±0.054	5.01±0.032	3.76±0.079	4.31±0.045
	C10		4.73±0.050	4.54±0.052	3.30±0.124	3.98±0.110
	C13		4.76±0.054	4.68±0.104	3.52±0.102	4.00±0.083
	C15		4.78±0.073	4.73±0.048	3.63±0.111	4.04±0.058
	C17		4.72±0.095	4.61±0.070	3.54±0.138	3.98±0.094
	C18		4.88±0.066	4.78±0.059	3.62±0.050	4.08±0.060
	C27		4.39±0.083	4.33±0.054	3.49±0.106	3.84±0.031
"Carrara" Glasses	D1		4.34±0.089	4.27±0.092	3.39±0.061	3.70±0.014
	D2		4.35±0.049	4.26±0.046	3.26±0.084	3.67±0.034
	D3		4.38±0.055	4.31±0.082	3.35±0.033	3.66±0.033
	D4		4.34±0.068	4.25±0.059	3.23±0.054	3.65±0.039

TABLE 10c

REPEATABILITY IN SIN MODE VS. SEX MODE

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

Textile Standards	Kollmorgen MS-2000		NARADCOM MS-2000		NARADCOM Hunter D54		NARADCOM Match-Scan	
	ΔE^*_{SIN}	ΔE^*_{SEX}	ΔE^*_{SIN}	ΔE^*_{SEX}	ΔE^*_{SIN}	ΔE^*_{SEX}	ΔE^*_{SIN}	ΔE^*_{SEX}
AG 344 P/W Gab.	0.07	0.08	0.06	0.09	0.14 (0.02)	0.05	0.07	0.06
OG 106 Ox./Nyl.	0.04	0.05	0.07	0.06	0.08	0.07	0.03	0.03
OG 107 Nyco. Pop.	0.05	0.05	0.04	0.04	0.06	0.18 (0.06)	0.04	0.05
OG 107 Ctn. B'loon	0.05	0.06	0.05	0.06	0.13 (0.10)	0.23 (0.09)	0.06	0.07
OG 107 Ctn. Sat.	0.05	0.04	0.04	0.05	0.21 (0.08)	0.10	0.10	0.10
OD7 Ctn. Duck MRWRP	0.18	0.18	0.21	0.21	0.07	0.09	0.08	0.09
Tan 46 Ctn. Pop.	0.04	0.05	0.04	0.05	0.06	0.08 (0.06)	0.08	0.05
AG 344 P/W Trop.	0.09	0.07	0.05	0.07	0.04	0.04	0.05	0.06
Tan 445 Twill poly./cot.	0.03	0.04	0.03	0.04	0.14 (0.15)	0.14	0.04	0.03
Blue 150 Gab./Wool	0.09	0.13	0.07	0.11	0.19 (0.08)	0.42 (0.06)	0.04	0.05
OD7 Ctn. Duck UTRD	0.08	0.10	0.11	0.10	0.09	0.08	0.05	0.06
AG 44 Wl. Serge	0.06	0.05	0.04	0.05	0.10 (0.04)	0.03	0.04	0.05
Tan M1 Cl. P/W Trop.	0.03	0.03	0.03	0.05	0.04	0.03	0.09	0.07
Blue 150 Trop. Wl.	0.06	0.10	0.08	0.10	0.26 (0.05)	0.08	0.05	0.07
OG 108 W/N Fl. Shirt	0.07	0.06	0.06	0.07	0.13 (0.05)	0.04	0.10	0.05
Blue 151 Wool Trop.	0.06	0.07	0.06	0.04	0.04	0.04	0.06	0.06

TABLE 10d

COMPARISON OF SIN MODE RESULTS VS. SEX MODE RESULTS

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

Textile Standard	$\overline{\Delta E^*}_{SIN\ vs.\ SEX}$ Kollmorgen MS-2000	NARADCOM MS-2000	NARADCOM Hunter D54P-5	NARADCOM Match-Scan
AG344 P/W Gab.	0.06	0.08	0.11 (0.07)	0.04
OG 106 Ox./Nyl.	0.06	0.08	0.12	0.09
OG 107 Nyco. Pop.	0.03	0.04	0.15 (0.10)	0.02
OG 107 Ctn. B'loon	0.04	0.03	0.11 (0.06)	0.04
OG 107 Ctn. Sat.	0.06	0.02	0.08 (0.08)	0.03
OD7 Ctn. Duck MRWRP	0.04	0.03	0.11	0.02
Tan 46 Ctn. Pop.	0.02	0.02	0.09 (0.07)	0.01
AG 344 P/W Trop.	0.01	0.05	0.11	0.01
Tan 445 Twill poly./cot.	0.06	0.05	0.07 (0.07)	0.03
Blue 150 Gab./Wool	0.05	0.03	0.11 (0.08)	0.05
OD7 Ctn. Duck UTRD	0.06	0.03	0.08	0.01
AG 44 Wl. Serge	0.04	0.04	0.08 (0.05)	0.04
Tan Ml Cl. P/W Trop.	0.02	0.04	0.13	0.03
Blue 150 Trop. Wl.	0.08	0.05	0.18 (0.05)	0.05
OG 108 W/N Fl. Shirt	0.04	0.04	0.08 (0.08)	0.02
Blue 151 Wool Trop.	0.05	0.05	0.07	0.03

TABLE 11

DIFFERENCES AMONG PHOTOMETRIC SCALES

Johnson Grey Tile	NARADCOM MS-2000 n	NARADCOM MS-2000 $\bar{Y}$	NARADCOM Hunter D54P-5 n	NARADCOM Hunter D54P-5 $\bar{Y}$	NARADCOM Match-Scan n	NARADCOM Match-Scan $\bar{Y}$	$\bar{\bar{Y}}$	$(\bar{Y}-\bar{\bar{Y}})$ NARADCOM MS-2000	$(\bar{Y}-\bar{\bar{Y}})$ NARADCOM Hunter D54P-5	$(\bar{Y}-\bar{\bar{Y}})$ NARADCOM Match-Scan
J7	12	0.49	13	0.99	15	0.79	0.76	-0.27	0.23	0.03
11616	11	6.02	16	6.71	15	6.34	6.36	-0.34	0.35	-0.02
J6	12	7.36	13	7.95	15	7.68	7.66	-0.30	0.29	0.02
J5	12	11.39	13	11.95	15	11.62	11.65	-0.26	0.30	-0.03
J4	12	29.50	13	30.04	15	29.49	29.68	-0.18	0.36	-0.19
9855	15	34.10	16	34.51	15	34.10	34.24	-0.14	0.27	-0.14
J3	12	62.10	12	62.28	15	61.94	62.11	-0.01	0.17	-0.17
9862	15	70.99	15	71.09	-		71.04	-0.05	0.05	-
J2	12	81.11	13	81.18	15	80.94	81.08	0.03	0.10	-0.14
J1	12	95.41	13	95.29	15	95.23	95.31	0.10	-0.02	-0.08
11672	15	100.00	16	100.00	15	100.00	100.00	0.00	0.00	0.00

TABLE 12a

POINT TO POINT SURFACE VARIATIONS - BCRA TILES: SEX MODE

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

BCRA Tile	Corner #1	Corner #2	Corner #3	Corner #4
Brown	0.23	0.16	0.03	0.05
	0.18	0.10	0.02	0.10
	0.52	0.23	0.13	0.10
	0.13	0.11	0.08	0.10
Pink	0.11	0.07	0.07	0.15
	0.08	0.02	0.11	0.11
	0.07	0.08	0.05	0.05
	0.12	0.14	0.11	0.07
Dark	0.12	0.45	1.22	0.38
Blue	0.10	0.47	1.11	0.46
	0.15	0.31	0.90	0.42
	0.16	0.37	0.83	0.10
Medium	0.05	0.03	0.03	0.12
Gray	0.03	0.01	0.02	0.11
	0.05	0.08	0.04	0.03
	0.02	0.03	0.04	0.02
Light	0.08	0.07	0.18	0.17
Gray	0.12	0.04	0.14	0.15
	0.15	0.06	0.09	0.17
	0.04	0.06	0.08	0.12
Yellow	0.45	0.05	0.07	0.16
	0.37	0.09	0.05	0.11
	0.39	0.09	0.04	0.16
	0.25	0.07	0.02	0.09
Light	0.12	0.03	0.09	0.05
Green	0.04	0.01	0.06	0.13
	0.06	0.10	0.03	0.06
	0.10	0.09	0.05	0.05
Dark	0.19	0.03	0.04	0.03
Green	0.10	0.02	0.06	0.06
	0.11	0.25	0.08	0.07
	0.12	0.08	0.05	0.03

TABLE 12a (CONT'D.)

BCRA Tile	Corner #1	Corner #2	Corner #3	Corner #4
Maroon	0.26	0.10	0.58	0.62
	0.09	0.06	0.35	0.56
	0.24	1.46	0.74	0.71
	0.05	0.09	0.48	0.22
Greenish	0.10	0.08	0.14	0.10
Blue	0.08	0.08	0.15	0.15
	0.07	0.09	0.22	0.21
	0.07	0.06	0.08	0.01
Medium	0.07	0.03	0.06	0.11
Blue	0.06	0.02	0.06	0.06
	0.08	0.09	0.13	0.10
	0.03	0.08	0.04	0.06
Dark	0.05	0.06	0.22	0.11
Gray	0.01	0.07	0.11	0.01
	0.07	0.06	0.06	0.05
	0.07	0.06	0.06	0.02

First line represents results from Kollmorgen MS-2000.
Second line represents results from NARADCOM MS-2000.
Third line represents results from NARADCOM Hunter D54P-5.
Last line represents results from NARADCOM Match-Scan.

TABLE 12b

POINT TO POINT SURFACE VARIATIONS - BCRA TILES: SIN MODE

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

BCRA Tile	Corner #1	Corner #2	Corner #3	Corner #4
Brown	0.20	0.20	0.12	0.05
	0.14	0.12	0.13	0.18
	0.26	0.31	0.17	0.08
	0.27	0.38	0.18	0.12
	0.39	0.53	0.35	0.28
Pink	0.08	0.04	0.11	0.14
	0.08	0.04	0.12	0.13
	0.06	0.06	0.05	0.09
	0.07	0.17	0.08	0.06
	0.14	0.06	0.17	0.12
Dark	0.07	0.26	0.74	0.30
Blue	0.04	0.24	0.68	0.31
	0.13	0.16	0.41	0.06
	0.11	0.39	0.63	0.08
	0.06	0.32	0.81	0.25
Medium	0.04	0.04	0.05	0.07
Gray	0.02	0.05	0.04	0.12
	0.06	0.03	0.04	0.07
	0.05	0.04	0.02	0.02
	0.06	0.05	0.11	0.13
Light	0.07	0.02	0.07	0.08
Gray	0.10	0.04	0.09	0.05
	0.08	0.02	0.05	0.08
	0.06	0.02	0.04	0.06
	0.14	0.13	0.11	0.15
Yellow	0.32	0.05	0.07	0.22
	0.30	0.09	0.09	0.18
	0.36	0.15	0.06	0.14
	0.26	0.15	0.07	0.05
	0.43	0.21	0.12	0.30

TABLE 12b (CONT'D.)

BCRA Tile	Corner #1	Corner #2	Corner #3	Corner #4
Light Green	0.09	0.03	0.07	0.07
	0.06	0.03	0.09	0.12
	0.06	0.04	0.05	0.05
	0.07	0.04	0.04	0.06
	0.07	0.14	0.16	0.12
Dark Green	0.12	0.01	0.03	0.13
	0.06	0.01	0.06	0.07
	0.13	0.08	0.03	0.08
	0.09	0.07	0.01	0.06
	0.11	0.06	0.02	0.07
Maroon	0.19	0.06	0.42	0.40
	0.11	0.07	0.30	0.40
	0.11	0.06	0.34	0.21
	0.11	0.13	0.38	0.17
	0.14	0.15	0.54	0.63
Greenish Blue	0.04	0.03	0.11	0.09
	0.05	0.05	0.11	0.12
	0.08	0.08	0.12	0.04
	0.08	0.06	0.06	0.04
	0.10	0.05	0.06	0.10
Medium Blue	0.06	0.02	0.05	0.08
	0.06	0.02	0.02	0.05
	0.04	0.08	0.03	0.05
	0.05	0.10	0.09	0.03
	0.07	0.05	0.05	0.04
Dark Gray	0.04	0.06	0.04	0.04
	0.04	0.06	0.05	0.05
	0.04	0.04	0.00	0.02
	0.05	0.02	0.01	0.04
	0.11	0.04	0.02	0.08

First line represents results from Kollmorgen MS-2000.
Second line represents results from NARADCOM MS-2000.
Third line represents results from NARADCOM Hunter D54P-5.
Fourth line represents results from Diano-Hardy II.
Last line represents results from NARADCOM Match-Scan.

TABLE 12c

POINT TO POINT SURFACE VARIATIONS - TEXTILE STANDARDS: SIN MODE

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

Textile Standard	Corner #1	Corner #2	Corner #3	Corner #4
AG 344	0.09	0.21	0.18	0.09
P/W Gab.	0.10	0.17	0.12	0.11
	0.08	0.20	0.13	0.17
	(0.09)	(0.19)	(0.13)	(0.16)
	0.09	0.17	0.12	0.14
OG 106	0.07	0.06	0.04	0.07
Ox./Nyl.	0.05	0.06	0.08	0.08
	0.34	0.19	0.26	0.21
	0.21	0.12	0.17	0.13
OG 107	0.09	0.04	0.23	0.18
Nyco. Pop.	0.09	0.04	0.18	0.14
	0.10	0.22	0.22	0.18
	0.11	0.13	0.18	0.16
OG 107	0.05	0.09	0.17	0.16
Ctn. B'loon	0.05	0.09	0.20	0.13
	0.16	0.08	0.21	0.19
	(0.20)	(0.09)	(0.23)	(0.19)
	0.28	0.09	0.24	0.14
OG 107	0.14	0.09	0.23	0.13
Ctn. Sat.	0.15	0.05	0.20	0 09
	0 20	0.11	0.22	0.12
	(0.20)	(0.12)	(0.22)	(0.12)
	0.10	0.10	0.19	0.08
OD7 Ctn.	0.11	0.19	0.42	0.34
Duck	0.14	0.22	0.43	0.32
MRWRP	0.12	0.17	0.28	0.25
	0.10	0.04	0.42	0.34
Tan 46	0.14	0.04	0.09	0.08
Ctn. Pop.	0.13	0.04	0.13	0.09
	0.09	0.07	0.15	0.10
	0.08	0.12	0.14	0.11
AG 344	0.16	0.24	0.02	0.13
P/W Trop.	0.16	0.21	0.10	0.19
	0.16	0.21	0.08	0.25
	0.12	0.23	0.03	0.23

TABLE 12c (CONT'D.)

Textile Standard	Corner #1	Corner #2	Corner #3	Corner #4
Tan 445	0.03	0.09	0.08	0.04
Twill	0.04	0.11	0.04	0.05
poly./cot.	0.04	0.02	0.03	0.02
	(0.03)	(0.01)	(0.02)	(0.02)
	0.03	0.01	0.09	0.03
Blue 150	0.05	0.04	0.08	0.09
Wool Gab.	0.04	0.01	0.04	0.05
	0.11	0.09	0.09	0.03
	(0.11)	(0.10)	(0.10)	(0.05)
	0.10	0.11	0.06	0.05
OD7 Ctn.	0.12	0.04	0.06	0.11
Duck	0.10	0.08	0.08	0.11
UTRD	0.09	0.26	0.19	0.30
	0.06	0.18	0.11	0.08
AG 44	0.03	0.05	0.03	0.04
Wl. Serge	0.08	0.11	0.02	0.03
	0.05	0.07	0.03	0.10
	(0.05)	(0.06)	(0.02)	(0.09)
	0.11	0.14	0.07	0.11
Tan M1	0.15	0.12	0.04	0.03
Cl. P/W	0.10	0.12	0.02	0.05
Trop.	0.13	0.09	0.05	0.09
	0.11	0.14	0.01	0.08
Blue 150	0.08	0.08	0.11	0.10
Trop. Wl.	0.03	0.13	0.10	0.09
	0.12	0.22	0.14	0.21
	(0.10)	(0.22)	(0.14)	(0.22)
	0.22	0.22	0.20	0.21
OG 108 W/N	0.12	0.12	0.22	0.05
Fl. Shirt	0.15	0.17	0.17	0.07
	0.14	0.14	0.18	0.09
	(0.16)	(0.16)	(0.18)	(0.11)
	0.10	0.14	0.10	0.06
Blue 151	0.05	0.03	0.10	0.06
Wool Trop.	0.02	0.05	0.07	0.03
	0.04	0.06	0.07	0.05
	0.06	0.00	0.07	0.09

First line represents results from Kollmorgen MS-2000.
Second line represents results from NARADCOM MS-2000.
Third line represents results from NARADCOM Hunter D54P-5.
Last line represents results from NARADCOM Match-Scan.

TABLE 13a

STATISTICAL FREQUENCY DISTRIBUTION OF STANDARD NORMAL DEVIATE OF X

PERCENTAGE OF POINTS WITHIN ± 1σ AND ± 2σ FROM THE MEAN

Textile Standard	Kollmorgen MS-2000		NARADCOM MS-2000		NARADCOM Hunter D54P-5		NARADCOM Match-Scan	
	± 1σ	± 2σ	± 1σ	± 2σ	± 1σ	± 2σ	± 1σ	± 2σ
AG 344 P/W Gab.	67.5	97.5	85.0	92.5	87.5 (68.6)	90.0 (97.1)	67.5	100.0
OG 106 Ox./Nyl.	67.5	100.0	72.5	92.5	65.0	97.5	72.5	100.0
OG 107 Nyco. Pop.	67.5	100.0	80.0	92.5	60.0	100.0	72.5	95.0
OG 107 Ctn. B'loon	75.0	95.0	75.0	97.5	80.0 (77.1)	95.0 (94.3)	67.5	100.0
OG 107 Ctn. Sat.	72.5	95.0	72.5	100.0	87.5 (65.9)	90 0 (100.0)	77.5	97.5
OD7 Ctn. Duck MRWRP	70.0	97.5	75.0	97.5	80.0	95.0	62.5	100.0
Tan 46 Ctn. Pop.	72.5	97.5	75.0	95.0	75.0	95.0	72.5	97.5
AG 344 P/W Trop.	70.0	97.5	70.0	100.0	70.0	100.0	82.5	100.0
Tan 445 Twill poly./cot.	72.5	100.0	67.5	97.5	77.5 (71.4)	100.0 (100.0)	77.5	95.0
Blue 150 Wool Gab.	72.5	95.0	85.0	97.5	87.5 (60.0)	87.5 (97.1)	70.0	97.5
OD7 Ctn. Duck UTRD	70.0	95.0	67.5	97.5	70.0	95.0	72.5	95.0
AG 44 Wl. Serge	65.0	95.0	70.0	100.0	87.5 (65.7)	90.0 (97.1)	72.5	97.5
Tan M1 Cl. P/W Trop.	80.0	92.5	75.0	95.0	75.0	97.5	62.5	97.5
Blue 150 Trop. Wl.	75.0	100.0	70.0	100.0	87.5 (80.0)	87.5 (97.1)	72.5	95.0
OG 108 W/N Fl. Shirt	77.5	95.0	75.0	100.0	82.5 (77.3)	92.5 (97.1)	65.0	100.0
Blue 151 Wool Trop.	72.5	97.5	77.5	95.0	85.0	92.5	72.5	100.0

TABLE 13b

STATISTICAL FREQUENCY DISTRIBUTION OF STANDARD NORMAL DEVIATE OF Y

PERCENTAGE OF POINTS WITHIN ± 1σ AND ± 2σ FROM THE MEAN

Textile Standard	Kollmorgen MS-2000		NARADCOM MS-2000		NARADCOM Hunter D54P-5		NARADCOM Match-Scan	
	± 1σ	± 2σ	± 1σ	± 2σ	± 1σ	± 2σ	± 1σ	± 2σ
AG 344 P/W Gab.	77.5	97.5	80.0	95.0	87.5 (65.7)	90.0 (97.1)	70.0	97.5
OG 106 Ox./Nyl.	77.5	97.5	77.5	97.5	60.0	100.0	80.0	100.0
OG 107 Nyco. Pop.	65.0	100.0	77.5	92.5	60.0	100.0	72.5	95.0
OG 107 Ctn. B'loon	67.5	95.0	80.0	97.5	80.0 (77.4)	95.0 (94.3)	72.5	100.0
OG 107 Ctn. Sat.	75.0	95.0	70.0	100.0	87.5 (65.7)	90.0 (100.0)	75.0	95.0
OD7 Ctn. Duck MRWRP	70.0	97.5	77.5	97.5	82.5	92.5	65.0	100.0
Tan 46 Ctn. Pop.	75.0	97.5	77.5	95.0	72.5	95.0	70.0	97.5
AG 344 P/W Trop.	70.0	97.5	67.5	100.0	62.5	100.0	70.0	100.0
Tan 445 Twill poly./cot.	82.5	100.0	70.0	97.5	75.0 (80.0)	100.0 (100.0)	72.5	95.0
Blue 150 Wool Gab.	70.0	95.0	75.0	95.0	87.5 (82.9)	87.5 (97.1)	70.0	95.0
OD7 Ctn. Duck UTRD	75.0	95.0	72.5	97.5	72.5	95.0	77.5	92.5
AG 44 Wl. Serge	72.5	100.0	80.0	100.0	87.5 (74.3)	87.5 (100.0)	70.0	100.0
Tan M1 Cl. P/W Trop.	77.5	95.0	75.0	95.0	72.5	97.5	67.5	97.5
Blue 150 Trop. Wl.	70.0	100.0	65.0	100.0	87.5 (68.6)	87.5 (100.0)	82.5	100.0
OG 108 W/N Fl. Shirt	77.5	92.5	77.5	97.5	80.0 (77.2)	92.5 (97.1)	65.0	100.0
Blue 151 Wool Trop.	77.5	97.5	80.0	95.0	70.0	92.5	70.0	97.5

TABLE 13c

STATISTICAL FREQUENCY DISTRIBUTION OF STANDARD NORMAL DEVIATE OF Z

PERCENTAGE OF POINTS WITHIN ± 1σ AND ± 2σ FROM THE MEAN

Textile Standard	Kollmorgen MS-2000		NARADCOM MS-2000		NARADCOM Hunter D54P-5		NARADCOM Match-Scan	
	± 1σ	± 2σ	± 1σ	± 2σ	± 1σ	± 2σ	± 1σ	± 2σ
AG 344 P/W Gab.	67.5	97.5	80.0	97.5	87.5 (65.8)	95.0 (100.0)	72.5	97.5
OG 106 Ox./Nyl.	60.0	95.0	82.5	92.5	65.0	100.0	77.5	97.5
OG 107 Nyco. Pop.	67.5	100.0	72.5	97.5	62.5	100.0	75.0	95.0
OG 107 Ctn. B'loon	77.5	97.5	80.0	92.5	77.5 (68.7)	95.0 (94.3)	72.5	100.0
OG 107 Ctn. Sat.	70.0	97.5	67.5	100.0	87.5 (71.5)	90.0 (100.0)	82.5	97.5
OD7 Ctn. Duck MRWRP	75.0	97.5	72.5	97.5	75.0	92.5	67.5	100.0
Tan 46 Ctn. Pop.	77.5	97.5	67.5	97.5	77.5	97.5	67.5	100.0
AG 344 P/W Trop.	75.0	97.5	70.0	100.0	67.5	100.0	67.5	100.0
Tan 445 Twill poly./cot.	75.0	95.0	77.5	97.5	82.5 (65.9)	92.5 (100.0)	72.5	97.5
Blue 150 Wool Gab.	72.5	97.5	75.0	97.5	87.5 (88.7)	87.5 (94.3)	80.0	92.5
OD7 Ctn. Duck UTRD	75.0	95.0	75.0	97.5	72.5	95.0	70.0	95.0
AG 44 Wl. Serge	72.5	100.0	62.5	100.0	87.5 (77.1)	90.0 (94.2)	62.5	97.5
Tan M1 Cl. P/W Trop.	72.5	97.5	70.0	97.5	75.0	97.5	72.5	97.5
Blue 150 Trop. Wl.	80.0	97.5	75.0	95.0	87.5 (65.7)	87.5 (97.1)	77.5	100.0
OG 108 W/N Fl. Shirt	77.5	100.0	72.5	97.5	80.0 (71.4)	87.5 (94.3)	70.0	100.0
Blue 151 Wool Trop.	70.0	95.0	80.0	97.5	75.0	95.0	70.0	100.0

TABLE 13d

STATISTICAL MEASURES OF SHAPE OF X STANDARD NORMAL DEVIATE FREQUENCY DISTRIBUTIONS

Textile Standard	Kollmorgen MS-2000		NARADCOM MS-2000		NARADCOM Hunter D54P-5		NARADCOM Match-Scan	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
AG 344 P/W Gab.	0.044	-0.826	0.417	0.291	-1.860** (0.120)	2.383* (-0.469)	-0.051	-0.765
OG 106 Ox./Nyl.	0.165	-0.636	0.257	0.113	-0.107	-0.984*	0.192	-0.699
OG 107 Nyco. Pop.	0.179	-0.839	-0.503	-0.079	-0.055	-1.006*	0.375	0.600
OG 107 Ctn. B'loon	0.302	0.725	-0.499	-0.133	-0.401 (0.785*)	0.345 (-0.262)	-0.357	-0.884*
OG 107 Ctn. Sat.	0.071	-0.217	-0.147	-1.157*	-1.564** (-0.053)	1.605* (-1.078*)	0.339	0.402
OD7 Ctn. Duck MRWRP	-0.243	-0.655	-0.231	-0.589	0.147	0.334	-0.094	-1.290*
Tan 46 Ctn. Pop.	0.689*	-0.089	0.053	-0.331	-0.207	-0.266	0.247	-0.801
AG 344 P/W Trop.	0.233	-0.408	0.058	-0.983*	-0.226	-1.111*	-0.192	-1.078*
Tan 445 Twill poly./Cot.	-0.741*	0.605	-0.106	-0.913*	0.070 (0.255)	-1.205* (-1.686*)	-0.826*	-0.012
Blue 150 Wool Gab.	0.175	0.407	0.753*	1.683*	-2.109** (0.036)	2.826* (-0.879)	-0.263	-0.230
OD7 Ctn. Duck UTRD	-0.259	-0.090	-0.249	-0.581	-0.054	-0.373	-0.387	-0.601
AG 44 Wl. Serge	0.371	-0.721	-0.230	-0.679	-1.885** (-0.430)	2.413* (-0.221)	-0.101	-0.767
Tan M1 Cl. P/W Trop.	0.689*	0.344	0.437	0.147	0.022	0.019	0.701*	-0.341
Blue 150 Trop. Wl.	0.408	-0.562	0.359	-0.566	-2.072** (0.348)	2.756* (-0.715)	0.848*	0.865
OG 108 W/N Fl. Shirt	-0.431	-0.423	0.217	-1.036*	-1.181** (0.221)	1.247* (-0.135)	0.067	-1.030*
Blue 151 Wool Trop.	-0.361	-0.089	-0.913**	0.643	-0.055	0.233	0.228	-0.796

*Significance at 0.05 level
**Significance at 0.01 level

TABLE 13e

STATISTICAL MEASURES OF SHAPE OF Y STANDARD NORMAL DEVIATE FREQUENCY DISTRIBUTIONS

Textile Standard	Kollmorgen MS-2000		NARADCOM MS-2000		NARADCOM Hunter D54P-5		NARADCOM Match-Scan	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
AG 344 P/W Gab.	0.187	-0.721	0.404	0.389	-1.893** (0.166)	2.511* (-0.633)	0.044	-0.607
OG 106 Ox./Nyl.	0.530	-0.409	0.387	0.100	-0.082	-0.993*	0.206	-0.972*
OG 107 Nyco. Pop.	0.097	-1.029*	-0.621*	-0.156	-0.103	-0.978*	0.255	0.054
OG 107 Ctn. B'loon	0.224	0.887	-0.607*	-0.009	-0.438 (0.811*)	0.455 (-0.147)	-0.271	-0.846
OG 107 Ctn. Sat.	-0.036	-0.555	-0.122	-1.242*	-1.538** (0.085)	1.620* (-1.117*)	0.087	0.243
OD7 Ctn. Duck MRWRP	-0.177	-0.724	-0.257	-0.652	0.205	0.168	-0.043	-1.233*
Tan 46 Ctn. Pop.	0.724*	-0.078	0.072	-0.365	-0.099	-0.182	0.297	-0.703
AG 344 P/W Trop.	0.184	-0.598	0.021	-1.003*	-0.235	-1.146*	-0.160	-0.968*
Tan 445 Twill poly./Cot.	-0.991**	1.556*	-0.257	-0.867*	0.054 (0.252)	-1.192* (-1.683*)	-0.685*	-0.279
Blue 150 Wool Gab.	0.157	0.112	0.517	0.958	-2.089** (0.122)	2.772* (-0.106)	-0.359	0.012
OD7 Ctn. Duck UTRD	-0.199	0.182	-0.193	-0.676	0.059	-0.458	-0.678*	-0.499
AG 44 Wl. Serge	-0.414	-0.965*	-0.168	-0.762	-1.844** (-0.300)	2.342* (-0.707)	0.010	-0.715
Tan Ml Cl. P/W Trop.	0.615*	0.375	0.538	0.457	0.121	0.016	0.545	-0.455
Blue 150 Trop. Wl.	0.354	-0.694	0.399	-0.707	-2.063** (0.226)	2.723* (-0.995*)	1.099**	1.077*
OG 108 W/N Fl. Shirt	-0.577*	-0.323	0.089	-1.063*	-1.106** (0.312)	1.070* (-0.282)	0.128	-0.974*
Blue 151 Wool Trop.	-0.295	-0.470	-0.982**	0.682	-0.061	-0.015	0.335	-0.481

*Significance at 0.05 level
**Significance at 0.01 level

TABLE 13f

STATISTICAL MEASURES OF SHAPE OF Z STANDARD NORMAL DEVIATE FREQUENCY DISTRIBUTIONS

Textile Standard	Kollmorgen MS-2000		NARADCOM MS-2000		NARADCOM Hunter D54P-5		NARADCOM Match-Scan	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
AG 344 P/W Gab.	0.094	-0.800	0.707*	0.258	-1.800* (0.338)	2.489* (-0.731)	-0.182	-0.582
OG 106 Ox./Nyl.	0.416	-0.450	0.756*	0.111	-0.061	-1.007*	0.279	-0.665
OG 107 Nyco. Pop.	0.096	-1.314*	-0.145	-0.586	0.157	-1.032*	0.120	-0.580
OG 107 Ctn. B'loon	-0.287	-0.118	-0.193	0.413	-0.349 (0.979**)	0.341 (0.114)	-0.383	-1.070*
OG 107 Ctn. Sat.	0.287	-0.110	-0.075	-1.089*	-1.669** (-0.075)	1.808* (-0.985*)	0.454	0.812
OD7 Ctn. Duck MRWRP	-0.166	-0.684	-0.169	-0.789	0.363	0.179	0.008	-1.170*
Tan 46 Ctn. Pop.	0.674*	-0.119	0.221	-0.585	0.065	-0.115	0.320	-0.686
AG 344 P/W Trop.	0.073	-0.509	0.004	-1.065*	-0.333	-1.132*	-0.202	-1.280*
Tan 445 Twill poly./Cot.	-0.952**	0.848	-1.181**	2.364*	-0.808* (0.064)	-0.013 (-1.539*)	-0.364	-0.980*
Blue 150 Wool Gab.	-0.090	0.701	0.181	0.175	-2.066** (-0.489)	2.718* (0.243)	-0.408	0.424
OD7 Ctn. Duck UTRD	-0.477	0.126	-0.150	-0.706	0.061	-0.528	-0.554	-0.561
AG 44 Wl. Serge	-0.342	-0.791	0.120	-0.688	-1.799** (-0.369)	2.234* (0.159)	-0.025	-0.874
Tan Ml Cl. P/W Trop.	0.672*	0.011	0.415	-0.181	-0.269	-0.445	0.390	-0.342
Blue 150 Trop. Wl.	0.273	-0.262	0.406	-0.249	-1.948** (0.191)	2.432* (-0.669)	0.977**	1.133*
OG 108 W/N Fl. Shirt	-0.108	-0.838	0.631*	-0.134	-1.339** (0.815*)	1.630* (-0.102)	-0.067	-0.671
Blue 151 Wool Trop.	-0.169	-0.704	-0.279	0.067	-0.429	0.383	0.452	-0.827

*Significance at 0.05 level
**Significance at 0.01 level

TABLE 14

SIGNIFICANCE LEVELS FOR LILLIEFORS TEST RESULTS

Textile Standard	Kollmorgen MS-2000			NARADCOM MS-2000			NARADCOM Hunter D54P-5			NARADCOM Match-Scan		
	Dx	Dy	Dz	Dx	Dy	Dz	Dx	Dy	Dz	Dx	Dy	Dz
AG 344 P/W Gab.						*	*		**			
OG 106 Ox./Nyl.		*	*	**		**				**	**	**
OG 107 Nyco. Pop.		*	*		*							
OG 107 Ctn. B'loon	**	*			*		*		*			**
OG 107 Ctn. Sat.				**								
OD7 Ctn. Duck MRWRP												
Tan 46 Ctn. Pop.										*		
AG 344 P/W Trop.									**	**	*	*
Tan 445 Twill poly./Cot.	**	**			*		**	**	**	*	*	**
Blue 150 Wool Gab.		*					**	**	**		**	**
OD7 Ctn. Duck UTRD	*									*		**
AG 44 Wl. Serge	*	*	**				*					
Tan Ml Cl. P/W Trop.	**		*							*	*	
Blue 150 Trop. Wl.	*	*					**	*		**	**	**
OG 108 W/N Fl. Shirt				**	*	*			**			
Blue 151 Wool Trop.	*			**	*		**	**		*	*	*

*Significance at 0.05 level
**Significance at 0.01 level

TABLE 15a

FRIEDMAN AND MULTIPLE RANK TEST RESULTS FOR K = 4 INSTRUMENTS AND N = 40 MEASUREMENTS AS REPRESENTED BY CIE Y

	1-2	1-3	1-4	2-3	2-4	3-4	
AG 344 P/W Gab.		*	*	*	*	*	
OG 107 Ctn. 8'loon		*	*	*	*		
OG 107 Ctn. Sat.		*	*	*	*	*	
Tan 445 Twill poly./Cot.		*	*	*	*		
Blue 150 Wool Gab.		*	*	*	*		
AG 44 Wl. Serge		*	*	*	*	*	
Blue 150 Trop. Wl.		*	*	*	*		
OG 108 W/N Fl. Shirt		*	*	*	*		N = 35
OG 106 Ox./Nyl.	*	*		*	*	*	N = 40
OG 107 Nyco. Pop.		*	*	*	*	*	
OD7 Ctn. Duck MRWRP	*	*	*	*	*		
Tan 46 Ctn. Pop.		*	*	*	*	*	
AG 344 P/W Trop.		*	*	*	*	*	
OD7 Ctn. Duck UTRD	*	*	*	*	*	Borderline	
Tan M1C1. P/W Trop.		*		*		*	
Blue 151 Wool Trop.		*	*	*	*	*	

Key

Instrument 1 = Kollmorgen MS-2000
Instrument 2 = NARADCOM MS-2000
Instrument 3 = NARADCOM Hunter D54P-5
Instrument 4 = NARADCOM Match-Scan

*indicates significance at the 0.01 level

TABLE 15b

FRIEDMAN AND MULTIPLE RANK TEST RESULTS FOR K = 8 (OR 7) WEEKS AND N = 20

MEASUREMENTS AS REPRESENTED BY CIE Y

	Weeks														
	1-2	1-4	1-5	1-6	1-7	1-8	2-5	2-6	2-7	2-8	3-5	3-6	3-7	3-8	4-8
AG 344 P/W Gab.														*	
OG 107 Ctn. B'loon							*			*					
OG 107 Ctn. Sat.															
Tan 445 Twill poly./Cot.										*		*	*	*	
Blue 150 Wool Gab.							*				*				
AG 44 Wl. Serge															
Blue 150 Trop. Wl.															
OG 108 W/N Fl. Shirt															k = 7 weeks
OG 106 Ox./Nyl.					*	*								*	k = 8 weeks
OG 107 Nyco. Pop.	*				*	*								*	
OD7 Ctn. Duck MRWRP		*	*	*	*	*		*	*	*		*	*	*	*
Tan 46 Ctn. Pop.															
AG 344 P/W Trop.															
OD7 Ctn. Duck UTRD			*	*	*	*			*	*	*	*	*	*	*
Tan MlCl. P/W Trop.					*										
Blue 151 Wool Trop.								*		*					

*indicates significance at 0.01 level

TABLE 15a

FRIEDMAN MULTIPLE RANK TEST RESULTS FOR K = 8 (OR 7) WEEKS AND N = 5

MEASUREMENTS AS REPRESENTED BY CIE Y

	Weeks											
	1-6	1-7	1-8	2-4	2-6	2-7	2-8	3-6	3-7	3-8	4-7	5-8
AG 344 P/W Gab.												
I1												
I2										*		
I3												
I4												
OG 107 Ctn. B'loon												
I1												
I2												
I3												
I4												
OG 107 Ctn. Sat.												
I1												
I2												
I3						*			*			
I4				*								
Tan 445 Twill poly./Cot.												
I1												
I2									*			
I3									*		*	
I4								*				
Blue 150 Wool Gab.												
I1												
I2					*							
I3												
I4												
AG 44 Wl. Serge												
I1												
I2												
I3												
I4												
Blue 150 Trop. Wl.												
I1												
I2												
I3												
I4												

Table 15c (cont'd)

	1-6	1-7	1-8	2-4	2-6	2-7	2-8	3-6	3-7	3-8	4-7	5-8
OG 108 W/N Fl. Shirt												
I1												
I2												
I3												
I4												k = 7
												k = 8
OG 106 Ox./Nyl.												
I1												
I2			*						*			
I3												
I4									*	*		
OG 107 Nyco. Pop.												
I1												
I2			*									
I3		*	*									
I4												
OD7 Ctn. Duck MRWRP												
I1		*	*			*	*					
I2		*	*				*					
I3	*		*									
I4	*		*									
Tan 46 Ctn. Pop.												
I1												
I2							*					
I3		*	*						*			
I4			*									
AG 344 P/W Trop.												
I1									*			
I2												
I3												
I4												
OD 7 Duck UTRD												
I1			*				*					
I2			*									
I3			*									
I4												

Table 15e (cont'd)

	1-6	1-7	1-8	2-4	2-6	2-7	2-8	3-6	3-7	3-8	4-7	5-8
Tan M1Cl. P/W. Trop.												
I1												
I2												
I3		*										
I4												
Blue 151 Wool Trop.												
I1									*			
I2					*							
I3												
I4												

I1 = Kollmorgen MS-2000

I2 = NARADCOM MS-2000

I3 = NARADCOM Hunter D54P-5

I4 = NARADCOM Match-Scan

*indicates significance at 0.01 level

TABLE 16

SHORT-TERM AND LONG-TERM REPEATABILITY OF COLOR MEASUREMENT

Instrument	Repeatability		
	Short-term Fluorescent	Short-term Non-Fluorescent	Long-term Carrara Glasses
Kollmorgen MS-2000	0.05 ± 0.025	0.04 ± 0.020	0.12 ± 0.090
NARADCOM MS-2000	0.03 ± 0.018	0.02 ± 0.010	0.06 ± 0.019
NARADCOM Hunter-D-54	0.03 ± 0.025	0.03 ± 0.014	0.06 ± 0.053
NARADCOM Match-Scan	0.03 ± 0.010	0.03 ± 0.007	0.08 ± 0.042

COLOR DIFFERENCES IN CIELAB UNITS FOR ILLUMINANT D65

TABLE 17

SHORT-TERM AND LONG-TERM REPEATABILITY OF COLOR MEASUREMENT

INSTRUMENT	REPEATABILITY		
	NBS SRM 2101-2105 Short-term	BCRA Tiles Long-term	Textile Standards Long-term
Kollmorgen MS-2000	0.06 ± 0.024	0.07 ± 0.037	0.08 ± 0.039
NARADCOM MS-2000	0.07 ± 0.033	0.05 ± 0.026	0.08 ± 0.043
NARADCOM Hunter D54	0.04 ± 0.035	0.07 ± 0.077	0.07 ± 0.028
		(0.09)	
NARADCOM Match-Scan	0.05 ± 0.035	0.07 ± 0.038	0.09 ± 0.038
Diano Match-Scan (Forward Mode)	0.06 ± 0.011		

Color Differences in CIELAB units for Ill: D65

TABLE 18

COEFFICIENTS OF VARIATION FOR NARADCOM PORCELAIN-ENAMEL COLOR-DIFFERENCE MEASUREMENT

Instrument	$\overline{\overline{Cv}}$
Diano-Hardy II	0.046 ± 0.021
Kollmorgen MS-2000	0.028 ± 0.010
NARADCOM MS-2000	0.027 ± 0.008
NARADCOM Hunter D54P-5 (n=3)	0.040 ± 0.023
NARADCOM Hunter D54P-5 (n=3)	0.031 ± 0.021
NARADCOM Match-Scan	0.028 ± 0.031

TABLE 19

SUMMARY OF EVALUATION OF COLOR DIFFERENCE PERFORMANCE ON TEXTILE SETS

Orientation	Grand Mean Coefficient of Variation		
	NARADCOM MS-2000	NARADCOM Hunter D54P-5	NARADCOM Match-Scan
0°	0.086 ± 0.048	0.054 ± 0.039	0.074 ± 0.034
45°	0.086 ± 0.035	0.060 ± 0.039	0.089 ± 0.051
90°	0.096 ± 0.046	0.057 ± 0.034	0.085 ± 0.062

TABLE 20

EXTENSION OF ANGULAR ROTATION STUDY

TEXTILE SAMPLE: OG 106 NYL./OX. - FULL STANDARD

INSTRUMENT: NARADCOM MATCH-SCAN

Angular Orientation	ΔE^* vs. 0°
45°	0.71 ± 0.051
90°	1.40 ± 0.036
135°	0.63 ± 0.093
180°	0.07 ± 0.035
225°	0.73 ± 0.055
270°	1.44 ± 0.045
315°	0.67 ± 0.067
360°	0.05 ± 0.000

TABLE 21

MEAN DIFFERENCES BETWEEN REFLECTANCE FACTORS IN SIN AND SEX MODES — CARRARA TILES

Instrument	Tile Color			
	Beige (D2)	Dark Blue (D3)	Dark Green	Pink
Diano-Hardy II	3.58	3.53	3.71	3.66
Hunter D54				
Normal	3.27	3.34	3.51	3.29
Light Trap	3.25	3.32	3.50	3.23
Rensselaer	3.26	3.35	--	--
NARADCOM MS-2000				
NARADCOM	4.42	4.45	4.59	4.51
Rensselaer	4.26	4.31	--	--

TABLE 22

AVERAGE COLOR DIFFERENCES FOR TEXTILE ACCEPTABILITY

NARADCOM Textile Set	NARADCOM MS-2000	NARADCOM Hunter D54P-5	NARADCOM Match-Scan	Grand Mean over 3 Instruments
AG 344 P/W Gab.	0.60±0.315	0.56±0.281	0.52±0.271	0.56±0.287
OG 106 Ox./Nyl.	2.49±1.411	2.43±1.346	2.45±1.318	2.46±1.340
OG 107 Nyco. Pop.	0.92±0.300	0.86±0.307	0.91±0.299	0.90±0.299
OG 107 Ctn. B'loon	1.32±0.490	1.56±0.518	1.61±0.516	1.49±0.516
OG 107 Ctn. Sat.	1.24±0.319	1.27±0.216	1.22±0.285	1.24±0.274
OD7 Ctn. Duck MRWRP	1.24±0.815	1.31±0.834	1.32±0.800	1.29±0.802
Tan 46 Ctn. Pop.	1.54±0.581	1.48±0.608	1.54±0.576	1.52±0.580
AG 344 P/W Trop.	1.54±0.668	1.72±0.672	1.58±0.656	1.61±0.661
Tan 445 Twill poly./cot.	0.88±0.793	0.85±0.724	0.84±0.722	0.86±0.737
Blue 150 Gab./Wool	0.29±0.127	0.35±0.080	0.31±0.105	0.32±0.108
OD7 Ctn. Duck UTRD	1.61±0.734	1.72±0.853	1.63±0.799	1.65±0.787
AG 44 Wl. Serge	0.36±0.083	0.38±0.070	0.39±0.077	0.38±0.077
Tan M1 Cl. P/W Trop.	0.59±0.342	0.55±0.334	0.58±0.322	0.57±0.329
Blue 150 Trop. Wl.	0.48±0.174	0.43±0.143	0.42±0.168	0.45±0.162
OG 108 W/N Fl. Shirt	1.09±0.325	1.08±0.353	1.13±0.388	1.10±0.352
Blue 151 Wool Trop.	0.71±0.263	0.71±0.239	0.72±0.249	0.71±0.247